Agriculture, Ecosystems and Environment 240 (2017) 269–275

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Efficiency of old and young shelterbelts in reducing the contents of nutrients in Luvisols

R. Jaskulska[a,*], J. Jaskulska[b]

[a] Institute for Agricultural and Forest Environment, PAS, Bukowska 19, 60-809 Poznan, Poland
[b] Institute of Environmental Engineering, Poznan University of Technology, Piotrowo 3a, 60–965 Poznan, Poland

ARTICLE INFO

Article history:
Received 29 July 2016
Received in revised form 22 February 2017
Accepted 27 February 2017
Available online 6 March 2017

Keywords:
Soil physical properties
Agricultural soil
Shelterbelt age
Topsoil
Nutrients
Groundwater

ABSTRACT

The purpose of this study was to determine the effect of shelterbelts as biogeochemical barriers that can reduce the concentration of nutrients in groundwater migrating from adjacent cultivated fields. The shelterbelts differed in age, trees species composition and soil organic carbon content. The investigations were carried out in Luvisols, in the western part of Poland. Soil samples were taken from the topsoil (0–20 cm) and then pH, soil organic carbon (SOC), total nitrogen (TN), exchangeable acidity, cation exchange capacity (CEC), particle size distribution, bulk density, porosity and hydraulic conductivity were analysed. Introduction of shelterbelts in a uniform agricultural landscape is one of the best ways for managing the water regime in the landscape. Surface runoff and percolation of water through a soil profile are controlled by shelterbelts. The studies conducted in the agricultural landscape showed that the 200-year-old shelterbelt (Old) with *Robinia pseudoacacia* L. as the dominant species and the 20-year-old (Young) multispecies shelterbelt effectively limit nitrate nitrogen (NO_3^--N) and phosphate phosphorus (PO_4^{3-}-P) in the groundwater. In the Old shelterbelt, the concentration of NO_3^--N was lower by 60%, and in the Young shelterbelt, by 22% in relation to the groundwater migrating from the adjacent cultivated fields. However, the concentrations of PO_4^{3-}-P decreased to 63% (Old shelterbelt) and 56% (Young shelterbelt) in comparison to the groundwater under the adjacent cultivated fields. In contrast to NO_3^--N, the ammonium nitrogen (NH_4^+-N) behaved in an entirely different way. The concentration of NH_4^+-N increased in the groundwater under both the Old and Young shelterbelts. The balance of nitrogen and phosphorus inputs and outputs in a shelterbelt indicated that the internal recycling of these elements is of crucial importance for the effective control of the spread of nitrogen and phosphorus compounds in the environment.

1. Introduction

Shelterbelts within fields are important instruments for ecological balance in the landscape. Together with stretches of grasslands, wetlands, small water reservoirs within fields and perennial crops, shelterbelts affect many physical, chemical and biological processes (Conant et al., 2001; Zyczynska-Baloniak et al., 2005). They form landscape structures known as biogeochemical barriers, which can modify non-point source pollution by the transport and cycling of nutrients and water. Intensive farming and acid rains have brought about a decrease of soil pH and an increase of mineralization processes in soil, resulting in higher leaching rates of chemical compounds from arable fields (Ryszkowski et al., 1999; Ryszkowski and Kedziora, 2007). Shelterbelts can also have a substantial effect on the microclimate within cultivated fields. Water circulation in the agricultural landscape is a process closely related to the flow of energy and matter transport (Kedziora and Olejnik, 2002). Percolation of rain and meltwater through the soil profile allows migration of chemical substances and soil colloids into the groundwater. Importantly, shelterbelts effectively take up chemical compounds that are dissolved in groundwater located within a range of well-developed root systems. Using trees for conservation affects the chemistry of groundwater and leads to landscape's better resistance to degradation. The shelterbelts reduce the spread of diffuse pollution generated by agriculture. The decline in water quality caused by non-point source inputs is not a recent phenomenon. Its effects became more noticeable because of greater regulatory, public and research awareness of this source of pollution (Szajdak et al., 2003). Filipiak and Komisarek (2005)

* Corresponding author.
E-mail addresses: renata.jaskulska@isrl.poznan.pl (R. Jaskulska), joanna.jaskulska@put.poznan.pl (J. Jaskulska).

http://dx.doi.org/10.1016/j.agee.2017.02.033
0167-8809/

showed that shelterbelts in upland parts of a watershed had additional cleansing effects on the groundwater if it was within direct or indirect (capillary rise) reach of the trees' root systems.

There are several key processes that need to be studied to understand the effects of shelterbelts on groundwater, such as infiltration, runoff, erosion, adsorption-desorption, and chemical transformations in the soil (Dexter, 2004a). Long-term studies on the function of shelterbelts within the Turew agricultural landscape, carried out by the Institute for Agricultural and Forest Environment, Polish Academy of Sciences, provided information on control of diffuse pollution in upland parts of drainage areas, which enriched the knowledge on control of non-point pollution outside riparian zones. The studies by Ryszkowski et al. (1999) also revealed some mechanisms for groundwater pollution control, which can be useful for developing a strategy for water resource protection.

This paper describes a continuation of the aforementioned research studies. It focuses on the effect of the 200-year-old shelterbelt with the dominant species *Robinia pseudoacacia* L. and multispecies young shelterbelt on the concentrations of NO_3^--N, NH_4^+-N and PO_4^{3-}-P in inorganic compounds in the groundwater of the agricultural landscape. It attempts to clarify the extent of mineral compounds migration with groundwater through a biogeochemical barrier. In addition, the results obtained from all the experiments should give a better insight into the changes that take place in the landscape with functional elements such as biogeochemical barriers.

Several publications have confirmed that changes in environmental conditions result in transformation of the ion balance in the soil environment, which is reflected by changes in pH and in, among others, the exchangeable cations ratio (Brandtberg et al., 2000; Hagen-Thorn et al., 2004).

The aim of this study was to estimate how shelterbelts in agricultural fields perform the function of biogeochemical barriers in relation to the migration of nitrogen and phosphorus compounds in groundwater.

2. Materials and methods

2.1. Description of study site

The study was carried out in the Chlapowski Agroecological Landscape Park near a small village called Turew (Poland, 52°01′ to 52°06′N and 16°45′ to 16°50′E). Geomorphologically, the research area is part of basal moraine of the Baltic glaciation, Leszno stadial, which terminated about 10,000 years ago. The terrain consists of a rolling plain made up of the slightly undulating ground moraine and many drainage valleys. Differences in elevation between higher and lower parts of the area do not exceed a few meters. The soil studied according to FAO–WRB (IUSS Working Group WRB, 2007) is a Luvisol formed from parent materials with favorable water infiltration properties (Marcinek, 1996). Agriculture is dominant in the region. The arable fields make up 70%, meadows and wetlands 12%, and forests and shelterbelts 16% of the area (Ryszkowski et al., 1999).

2.2. Characterization of the study site

Mean annual solar radiation is 3700 MJ m^{-2} and the average annual air temperature is 8 °C (range 6.9–8.5 °C). Mean annual precipitation is 594 mm of which 365 mm falls in the period from April to September. The actual evapotranspiration is 522 mm, which makes the water balance very small (Ryszkowski and Kedziora, 2007).

The research concerned Luvisols in a cultivated field-shelterbelt system at two sites with different scenarios. The arable lands have been cultivated intensively for many years. Mineral fertilization of NPK in the cultivated fields adjacent to shelterbelts ranged from 180 to 250 kg ha^{-1}, and from 220 to 290 kg ha^{-1} for the Old and Young shelterbelts, respectively.

The shelterbelts within fields differed in age, tree species composition and organic carbon content in the topsoil. The geographical position of these shelterbelts is in a North-South direction.

The first site was a cultivated field with a 200-year-old shelterbelt (Old) with a length of 800 m and a width of 36 m. The dominant species is a non-native species *Robinia pseudoacacia* L. (97%). Other species are native – *Alnus glutinosa* Gaertn. (1.6%), *Quercus petraea* (Matt.) Liebl. (0.5%), *Quercus robur* L. (0.3%), *Acer platanoides* L. (0.4%) and *Sorbus aucuparia* L. (0.2%).

The second site includes a cultivated field and a within-field shelterbelt with a length of 340 m and a width of 18 m, established in 1993 (Young) on the initiative of the Department of Agricultural and Forest Environment PAS. This shelterbelt comprises *Tilia cordata* Mill. (10%), *Larix deciduas* Mill. (9%), *Pinus silvestris* L. (9%), *Populus nigra* L. (9%), *Sorbus aucuparia* L. (9%), *Sorbus intermedia* (Ehrh.) Pers. (5%), *Betula pendula* Roth (8%), *Acer pseudoplanatus* L. (8%), *Fraxinus excelsior* L. (8%), *Quercus robur* L. (7%), *Quercus petraea* (Matt.) Loebl. (7%), *Picea abies* (L.) H. Karst. (5%), *Alnus glutinosa* Gaertn. (4%), *Ulmus laevis* sp. (4%) and *Fagus silvatica* L. (2%), planted in 11 rows.

2.3. Chemical analysis of groundwater and physicochemical analysis of soil

Groundwater samples for analyses were collected monthly from April to September 2009 and from March to September 2010 from perforated wells made from PVC pipes. The four wells were installed 300 cm deep in the middle of shelterbelts and in adjacent cultivated fields 100 m from the shelterbelts. The height of the water table was about 200 cm in the Old shelterbelt and adjacent cultivated field, and about 300 cm in the Young shelterbelt and adjacent cultivated field. Before sampling, stagnation water was pumped out every time. Based on the hydroizohips method, which consists of continuous determination of differences in groundwater table depth relationship to sea level, the direction of flow due to the force of gravity was determined. Appling these methods, we chose those watershed fragments in which shelterbelts were located in the main direction of groundwater outflow from neighboring cultivated fields. Within a radius of 1 m around each well, soil samples were taken from the topsoil (0–20 cm) of cultivated fields located 100 m from the shelterbelt and in the middle of the shelterbelt areas at 10 sites. Smaller samples were bulked to prepare a mean sample used to determine the physicochemical properties of the soil. In addition, three replicates of undisturbed samples were taken in cylinders with a volume of 250 cm^3 and 100 cm^3 to determine hydraulic conductivity and bulk density, respectively. The soil samples were air-dried and sieved through a 2-mm diameter sieve. Analyses of soil samples and groundwater were performed in triplicate and average values were considered to be representative.

Soil samples were analysed according to the methodological procedures described by (Mocek et al., 2000) and Van Reeuwijk (2002). The particle size distribution was determined in the samples. The sand was fractionated by dry sieving, while the clay and silt fractions were determined using the hydrometer method. Contents of sand (2.0–0.05 mm), silt (0.05–0.002 mm) and clay (<0.002 mm), (Van Reeuwijk, 2002) were determined, according to the standard PN-ISO 11277 (2005). The particle density was established using the picnometric method. The bulk density was assessed in undisturbed soil samples taken in metal rings of 100 cm^3 using the oven-dry method (at 105 °C). Porosity was