Folia Forestalia Polonica, series A, 2009, Vol. 51(1), 5–11

ORIGINAL ARTICLE

Farmland afforestations: new goals and guidelines for Poland

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Abstract

Farmland afforestations (FAs), i. e. groups of trees and shrubs scattered in agricultural landscape, were for long considered mostly as supplementary timber resource and wind mitigation tool. The contemporary shift to other, environment- and social-related functions of FAs is discussed in the paper and example guidelines for the establishment of new FAs proposed. The concept of "farmland afforestations' needs" is presented as a tool to incorporate FA issues in land- use planning.

Key words

farmland afforestation, shelterbelt, agricultural environment, land-use planning

Introduction

This paper discusses the ways a woody vegetation may be used to enhance the goods and services offered by agricultural landscape, which are a key concept of multifunctional open land use theory Constanza *et al.* 2003, Mandner *et al.* 2007).

Definition of farmland afforestations

Many different terms are used to describe woody vegetation in agricultural landscapes: shelterbelts, windbreaks, woodlots, landscape trees, buffer zones, midfield forests, forest islands, hedges, agroforestry and silvopastoral systems, which follows different research approaches (structural, spatial or functional). Regardless of diversity observed, a common name of farmland afforestations (abbreviated FAs) was used throughout this paper.

We define FAs as "trees and shrubs scattered in agricultural landscape, growing in groups, rows, belts or as isolated individuals, not forming forest communities, with ground they cover and other vegetation components". This definition, elaborated originally by Zajączkowski (1982) as a result of research in former Laboratory of Fast Growing Plantations and Farmland Afforestations, Forest Research Institute in Sękocin, is being used in Nature Protection Act and some other official documents in Poland. It does not include urban greenery and open wilderness areas (not managed by means of agriculture).

According to current Forest Act, the minimum area of woody patch in the field to be considered a forest is

Received 1 January 2009 / Accepted 1 February 2009

0.1 hectare only. In fact, no autonomous forest vegetation communities nor inner-forest microclimate features may occur at such small patches, because of border effects (Ranney and Bruner 1981), which penetrate the patch's buffere zone as deep as 30-50 m at least (Fig. 1). The prevailing role of externally-oriented energy and resource flows is the most apparent difference between FAs and forests (Ryszkowski and Kędziora 1987, Ryszkowski *et al.* 2000). Thus, we consider forest islands up to 1 ha as large FAs.

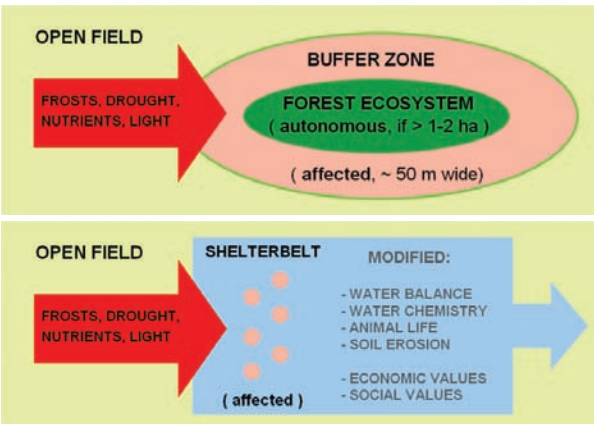

Fig. 1. Border effect influence on effective minimum forest island area (upper) and shelterbelt effects on adjacent field area (down)

Brief history of FAs in Poland

According to literature survey by Zajączkowski (2005), trees were planted along countryside roads in Poland since XVII c., to give shadow in summers and mark road direction during snowy winters. First written remarks on trees as means to improve agricultural landscape quality come from "Practical botany manual" by Kluk, published in 1778. Since 1820-ties, new ideas on using trees and hedges to improve field crop effects started to spread, as result of a Napoleon-era Polish general Chłapowski visit to Great Britain.

First law regulations on farmland afforestations were issued in 1921, only two years after the re-establishment of Polish State had cancelled over 100-year partitioning. The Road Act recommended planting trees and/or hedges along all public roads, also on adjcent private properties if necessary, with preferences given to fruity species. After demolishing II world war time, a "million trees for the State millenium" goverment initiative (1966) encouraged local authorities to plant trees on rural areas to increase timber production and mitigate wind-caused environmental problems. With priority given to fast growing species (mostly cultivars of Poplar *Populus ssp.*), it increased the FAs' growing stock to maximum 3% of that for total forest area in 1980-ties. Since then, trees have been cut off along many roads, due to unclear law protection status and growing traffic accidents risk. Roadside re-planting activities have became significant in last years only.

Current acts on Polish environmental policy – e. g. State Forestry Policy (1996) and State Ecological Policy (2000) – consider management of FAs as a particular task in national programmes for sustainable development and environment protection (Ryszkowski and Bałazy 1995).

Modifying the agricultural environment with trees

Goals and functions of FAs

Two main directions are recognized, at which FAs may influence human environment on rural areas: (1) protecting landscape against environmental threats and (2) improving its economic and social usefulness (Zajączkowski 2005). More precise role descriptions are necessary, however, when discussing the planning and management of FAs. As a result of numerous field observations and analyses of other authors' case studies, a set of detailed functions of FAs has been determined, which consists of three main function groups – protective, productive and social (Zajączkowski 1989, Gómez Sal and González García 2007). During last 40 years, the protective functions have been gradually recognized as the most important for agricultural landscape (Bałazy 2002, Ryszkowski *et al.* 1996), which now stands in clear opposition to former, timber-oriented trends.

The following protective functions, of explicitly spatial type, were chosen as suitable for application in land management planning procedures (Zajączkowski 2005): water balance improvement, watershed source areas protection, water- and soil erosion mitigation, protection against air and water pollution, recultivation of postindustrial soil substrates, increasing the environment resistance to crop pests, protection of natural biocenoses, improving the environments for animals of economic role (the cattle, the game, honey bee and wild bee pollinators), controlling the snow distribution on fields and along roads, increasing thermal comfort on pastures and farms.

FAs in agricultural landscape are generally multifunctional – as do cultural landscapes themselves (Mander et al. 2007) – which means that for virtually each patch of woody vegetation different supplementary (even contradictory) functions may be observed and/or proposed apart from the leading one. This feature should be taken into account when planning new FAs establishment or reshaping the existing shelterbelts (Zajączkowski et al. 2001, Bałazy 2002). The decision space of FAs' design consists of location (roadsides, stream valleys, non-productive patches, etc.), shape (one- or two tree storeys, with or without hedgerow), species selection (mostly native) and spatial arrangement, planting distances, seedling features, weed control methods, picketing, fencing, tree pruning, hedges cutting, etc. To ease species selection with respect to functions, locations, site and structural features of FAs, a computer program EKSPERT has been developed (Zajączkowski 1998) and published on Polish Ministry of Environment web page (www.mos.gov.pl).

Guidelines for FAs establishment to improve local water balance

The negative water balance during growing season, dropping below -100 mm for many parts of Polish Lowlands, is considered main environmental obstacle to increase the effectiveness of agriculture (Ryszkowski *et al.* 1996, 2003). Water loss on agricultural land, both due to transpiration and run-off, is also hazardous to biological life. According to Ryszkowski *et al.* (2003), two-thirds of small open water areas disappeared during last 70 years in Wielkopolska region of intensive agriculture, which was followed by significant animal and plant species diversity loss.

Numerous research results, e. g. from Research Center for Agricultural and Forest Environment in Poznań, western Poland, have proven that farmland afforestations of linear type (shelterbelts: made of 1-6 tree rows, possibly accompanied by shrubs) may effectively modify wind velocity on large areas, reducing soil and crops transpiration as well as snow blowing away the fields (Ryszkowski and Kędziora 1987).

About 40% horizontal crown penetrability of shelterbelt is suggested to maximize the range, at which wind close-to-ground velocity – key factor for evapotranspiration – is significantly mitigated (Fig. 2). To obtain such structure, one or two rows of trees should be planted, made of wind resistant, leaf-rich and high species, with row of shrubs underneath to close "nozzles" below the crowns. As the effective range of shelterbelt reaches no more than 15 (5-20) multiples of its final height, the agricultural landscape should be partitioned with subsequent shelterbelts, located perpendicularly to prevailng wind direction, at mutual distances up to 300-400 m, linked together by supplementary hedgerows.

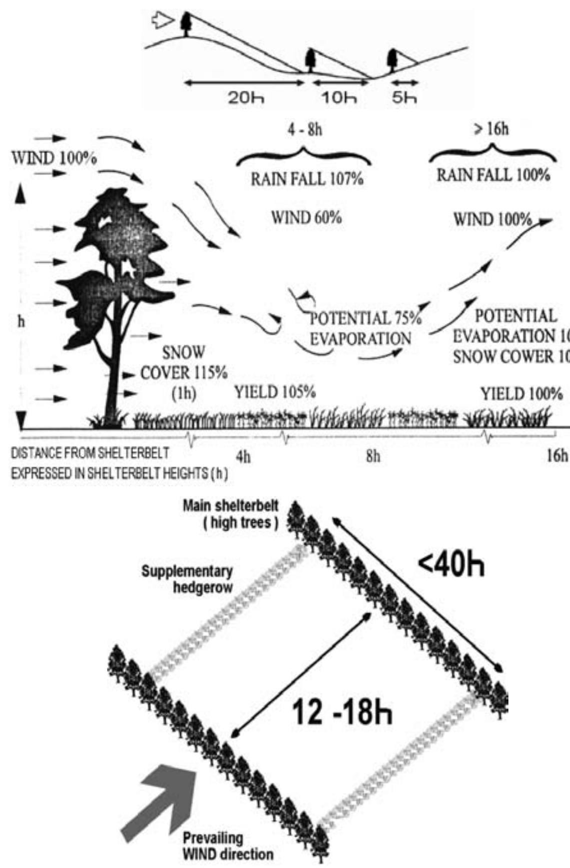

Fig. 2. Effect of shelterbelt on adjactent field, effect of shelterbelt location in hilly areas on wind mitigation range and locating guidelines for new shelterbelt of wind mitigation function

Guidelines for FAs establishment to protect water quality

Apart from making costly and environmentally harmful high embankments, no mechanical construction may be effectively used to prevent nutrient and pesticide diffusion from fields to open water reservoirs – streams, lakes etc. (Bałazy 2002, Ryszkowski *et al.* 2003). Pollutants may leak to waters both as surface- or in-depth run-off. The level of pollution depends on slope, soil properties and culture type. No surface run-off is observed on meadows and pastures, due to well developed sod (grass roots) soil layer, as opposite to arable land.

Pumping ground-water solution with roots, trees and shrubs along water banks as well as grassy vegetation beneath prevent surface- and diminish in-depth run-off (Ryszkowski *et al.* 2002). The nitrates content in ground-water diffusing through the trees' root layer is reduced up to 20 times, the most spectacular example of high effectiveness of biogeochemical barriers formed by FAs (Szajdak *et al.* 2002).

When planning establishment of FAs to protect water quality, different measures are undertaken according to pollution risk level. Up to 10-m wide belt of ground along the water bank should be excluded from cultivation on areas of the highest risk (arable land on high slope, erodable soil), then planted with loosely-spaced trees and shrubs of dense root system and light-passing crowns, and sawn with grass – to prevent surface water run-off and also weed expansion. Where meadows approach the water line, only one row of densely-spaced trees may be planted to help clear the ground-water. On pastures, additional rows of trees and thorny shrubs are adviced to control increased nitrogen load, prevent the banks crushing and provide the animals shelter from sun and cold winds.

Guidelines for FAs establishment to enhance biocenotic relations

Open geochemical cycles of water and nutrients as well as biological unstability are common features of vast arable land ecosystems. The threat of cyclic mass pest gradations forces to choose between polluting pesticides application or counting on predators' ability to control the pests. Only few predatory species, however, may survive unfavorable open area conditions: harsh microclimate, lack of shelter and food shortages (Forman and Godron 1986, Ryszkowski *et al.* 1996).

Patches and lines of woody vegetation divide the agricultural landscape into smaller, unique units and create new edges (Ranney and Bruner 1981, Mander *et al.* 2007). Many case studies prove that this way the FAs positively influence wild species diversity and population densities, including predators and facultative predators (Kujawa 2000, Balent *et al.* 1992, Monteil *et al.* 2005, Ouin *et al.* 2006, Heroldová *et al*. 2007).

To create a refuge area for different species, the FAs in a given area must conform to particular location and structure rules (Zajączkowski 2001, Bałazy 2002). The distance from any point of the field to the nearest woody refuge area should not exceed 150-200 m, an affordable penetration range of medium-sized predatory mammals and birds. This implies the net type of FAs' spatial structure, with long, thin corridors connected to larger patches (net nodes). Wider corridors should be maintained between isolated forested areas in agricultural landscape, and long-distance connections established to enable animal migrations (Jongman *et al.* 2003). Significant share of thorny and fruity shrub species is necessary to provide breeding places, shelter and facultative food sources for animals. Among 1-2 native tree species forming the FAs' upper layer, single specimens of higher (fast growing) species should be scattered as watching places for large birds of prey.

The concept of farmland afforestations' needs

The environmental hazards are usually observed in large spatial scales, exceeding the scale of local agricultural landscape (Zajączkowski 2005). The water balance deficit, soil erosion or biological instability are common features of whole geographical units (Kondracki 1998): mesoregions (318 units in Poland) or macroregions (56 units). Mesoregions, with average area of ca 1000 sq. km., are considered the lowest physiogeographic regionalization units used to study natural processes and phenomena at the country level (Kondracki 1994) and were chosen by Zajączkowski (2005) to study the spatial distribution of agricultural landscape features, which are related to, or may be modified by, the presence of FAs. The concept, some of the study results and further application suggestions are presented below.

The concept

As mentioned above, the goods and services offering by agricultural landscape may be enhanced with proper application of FAs. A method is proposed to enable detecting which values the FAs are capable to affect in particular area, i. e. what functions should the FAs fulfil there. This method, called farmland afforestations' needs assessment, uses different sources of spatial and statistical information on local environment, economy and social issues to select leading functions of FAs and assess urgency for new FAs establishment (Fig. 3).

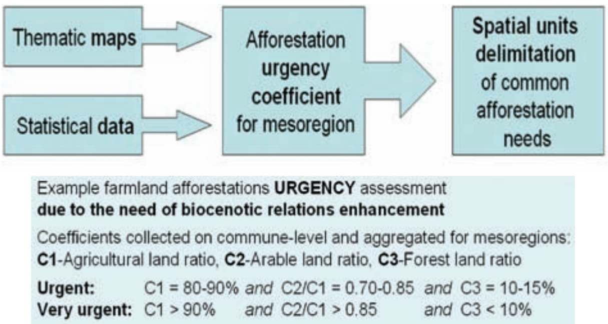

Fig. 3. The assessment of farmland afforestations' needs for selected function schema (top) and FAs urgency calculation example (down)

The map of potential soil erosion or map of soil drying up disposition are example sources of spatial data on agricultural environment. Statistical year-books and queries on local administration office files are main sources of descriptive (non spatial) data.

Results

As result of data aggregation and generalization, 12 different afforestation needs' types of regional or country-wide importance were selected. Taking together mesoregions of similar afforestation needs (expressed as leading functions of FAs), 70 continuous and relatively homogenous regions were dinstinguished in Poland. Along with this map of FAs leading functions' distribution, a separate map was prepared to detect the areas of the highest FAs establishment urgency (Fig. 4).

Water balance deficit and wind-caused soil erosion appear to be main sources of hazards to agricultural environments and economy on Great Lowlands (central Poland). In some regions water-caused erosion and biocenotic instability are also the problems. We suggest urgent new FAs establishment to enhance, or create in some places, a landscape service capable to mitigate hazards and thus improve both the environment stability and economy effectiveness. The spatial and structural features of new plantings should conform to models elaborated for each leading function of FAs (see example guidelines above).

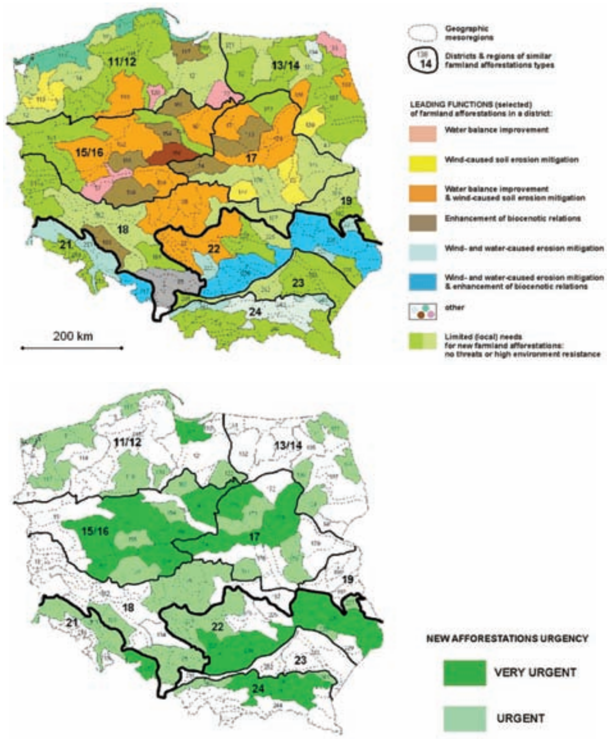

Fig. 4. Distribution of farmland afforestation leading functions (upper) and afforestation urgency (down) in Poland

Implementation issues for land-use planning

Only spatially continuous and properly designed FAs are capable to effectively mitigate large-scale environmental threats in agricultural landscape (Ryszkowski *et al.* 2000). Because of spatial dimension of most FAs-related environmental issues, the land-use planning procedures seem to be suitable tools to introduce new FAs and trace the status of existing ones. We suggest the following ideas to be incorporated into standard regulations on local land-use planning.

(1) Obligatory analysis of FAs applicability to stabilize environment should identify areas of urgent need for FAs establishment to mitigate threats in the environment and, possible, improve its usefulness for local society.

(2) As a result, a set of minimum requirements should be provided (acceptable spatial, species and structural features) for existing and new farmland afforestations for each selected area.

(3) A financial compensation, at the level of real crop production loss at least, should be offered by regional governments to land owners where FAs exist, which conform to relevant requirements of land-use plan.

(4) Continued FAs features' conformance to the requirements (controlled by field inspections or remote techniques) should be necessary condition of compensation payments periodical renewals.

Conclusions

Farmland afforestations may be actively used on rural areas to stabilize agricultural ecosystems and also improve economy and human life quality.

Detailed guidelines exist on determination of afforestation needs as well as new afforestations design and establishment procedures.

Land owner benefit losses result from introduction of FAs to enhance common values of agricultural environment. To effectively control the necessary public financial compensation system, the implementation of land-use plan regulations is adviced.

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