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TREES OUTSIDE FOREST IN POLAND

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ABSTRACT: Increasing environmental threats to agricultural production and the stability of ecosystems have been observed on the Polish lowlands since the 1970s. Several hundred million trees and shrubs have been planted on farmland, mostly along roads and with the involvement of public agencies, with a view to timber being produced, and soil erosion and the water deficit mitigated. On the basis of over 50 years of practical observations and scientific experiments, recommendations have been drawn up as regards the structural and spatial features of new tree planting outside forests that maximize environmental, production-related and social benefits. This paper gives a brief description of the history of the active establishment of woody vegetation across agricultural landscapes in Poland, along with best practices elaborated for this at several scientific centres.

KEY WORDS: windbreak, shelterbelt, groundwater contamination, soil erosion, biodiversity, tree planting, greening.

INTRODUCTION

The term '**T**rees **O**utside **F**orest' (TOF) has been used in this paper to denote a unique Polish word 'zadrzewienia', which includes different functional and structural types of woody vegetation in agricultural landscapes; be these shelterbelts, windbreaks, landscape trees, buffer zones, midfield forests and woodlots or, hedges, or examples of agroforestry and silvopastoral systems. The technical definitions of TOF in Polish legislation often enumerated their relevant locations (e.g. by a road or railway) or spatial features (e.g. a valid range of values for crown area). The recognition of the ecosystem-related values of TOF has led to a more general definition (Zajączkowski 1982): "trees and shrubs scattered in the agricultural landscape, growing in groups, rows, belts or as isolated individuals, not forming forest communities, along with the ground they cover and other components of vegetation".

Patches of TOF offer a wide range of ecosystem services (Mander *et al.* 2007, Schneiders *et al.* 2012), specific to distinct components of agricultural landscape, e.g. arable land, meadows and pastures, small settlements and places of leisure, roads and railroads, the margins of streams, rivers, canals, lakes and ponds, small dumping grounds and sites left after the excavation of gravel, sand or clay. There are particular locations in the open landscape, in which TOF do not offer ecosystem services as primary products or functions. For example, the woody vegetation in orchards, tree nurseries, manor parks, churchyards, cemeteries, etc., is not the subject of TOF planting projects or management plans.

Patches of TOF differ from forests in their more limited spatial extent, prevailing external direction of energy and resource flows (Ryszkowski and Kędziora 1987, Ryszkowski and Bartoszewicz 1989), the greater importance of border-zone effects, as well as the specific management goals and methods. In line with FAO regulations (UN-ECE/FAO 1997), the minimum area of a single forest patch of this kind is 0.5 ha. Poland's Forest Act (1991) in turn sets the minimum forest area at 0.1 ha only, in this way ensuring that the abundant small private forest properties are kept under its protection. From the ecological point of view, woody areas below 0.5–1.0 ha cannot be considered autonomous forests, being subject to severe external influences caused by wind, light, frosts, nutrients or biotic agents (Ranney and Bruner 1981, Żarska 1994). Thus, we consider such small forest areas as an important variant of TOF, complementary to the larger midfield areas of forest (Zajączkowski and Zajączkowski 2009).

TOF may appear in different spatial structures, from which linear forms (rows, alleys and belts) are most common. The vertical structure of a TOF patch may comprise a main tree layer and an understory tree and/or shrub layer. The shrub layer may also exist independently (without trees) and may be grown free or as a cut hedgerow or naturally regenerated patch.

TREES OUTSIDE FOREST IN POLAND – A BRIEF HISTORY

In addition to the common ancient practice of planting trees within areas of settlement, TOF have been planted in Poland along countryside roads since the 17th century, most commonly along the approaches to the estates of the nobility (Zajączkowski 2005). The most beautiful contemporary avenues of trees in Poland originated over 200 years ago in the Pomerania and East Prussia regions, then owned by the Prussian Kingdom, whose laws promoted tree planting along roads for military reasons. Midfield trees have been planted to improve crop efficiency since the 1820s, when general Dezydery Chłapowski from the Turew Estate in Poland's Wielkopolska Province first brought in British ideas on modern agriculture.

Polish legal regulations on by-road trees were issued as recently as in the 1920s, the delay reflecting the absence of the Polish State for over 120 years. The Road Act from 1921 obliged road-maintenance authorities to plant trees and/or hedges along all public roads, with preferences given to fruit-producing tree species. The owners of fields adjacent to narrow road grounds were to leave 75 cm-wide strips for trees or electricity poles. The Act protected TOF from arbitrary cutting and damage: crossing attendant posts were kept along important roads and the permission of the Public Works Minister or provincial governor was required for the removal of all trees from along avenue sections. TOF planting by school children and volunteers was encouraged by local offices of the State Forests enterprise, the largest forest owner in the country, as a supplementary task to afforestation projects. Altogether, more than 5.5 million new trees were planted by roads before World War II.

The largest numbers of trees and shrubs (over 120 and 145 million, respectively) were planted in agricultural landscapes as result of the "Hundred million trees for the State millennium 1966" governmental initiative of 1959, which encouraged local authorities to plant trees on public land to increase timber production and mitigate wind-caused erosion and drought. Priority was given to fast growing species – i.e. cultivars of Poplar *Populus ssp.* Trees as windbreaks were also planted on large state-owned farms – on pastures or on the rich Vistula Delta croplands. As a result, the growing stock of TOF in Poland, relative to that of forests, reached its 3% maximum in the 1980s, this being recalculated to 1–2% of the field area covered by live crowns (Zajączkowski 2005). Among the many practical experiences gained in that period, new dimensional and qualitative standards for planting material were elaborated by the then Trees Outside Forest Department of the Forest Research Institute (*Norma branżowa…* 1977), these differing from those applying to trees planted in forests, urban green space or fast-growing plantations. Given that planting locations outside forests are usually characterized by a harsher microclimate, a lack of watering or other care and a major possibility of damage being inflicted by game or farm animals or machinery, both a specific species composition and unique features of planting material were recommended, i.e. relative frost resistance, very good health status, larger initial dimensions and greater age at the time of planting, a moderate shoot/root length ratio, with roots being shortened at the nursery 1–2 years before planting out in order to

make the root system more dense and vital (Zajączkowski 1999). Special nurseries were established on more than 40 00 hectares of State Forests land, with a view to distinct types of seedlings for farmland being produced.

Over the last 30 years, trees have been cut along many roads, as a result of new regulations on traffic safety and local government. These removals were seldom offset by planting of new trees, except thanks to the efforts of certain green NGOs. In contrast, additional protection measures were laid down for trees growing on agricultural land away from roads by the Nature Protection Act of 2004, this introducing local-authority permits and, in some cases, fees or fines to which land owners are to be subjected, in cases of the removal of trees aged 10 years or over.

The 'greening' concept, implemented since 2015 under the Common Agricultural Policy of the European Union, established a new framework for the promotion of TOF. The direct agricultural payments made to larger farms were made conditional on keeping 7% of land biologically active. Apart from specific land-use categories and crops, this concept takes areas of TOF into account, whether trees are growing as singletons (with crowns at least 4 m wide), in rows or belts (up to 10 m wide) or in patches (covering up to 0.3 ha). Non-woody buffer zones and baulks are also taken account of. The regulation provides, for the first time ever in Poland, that financial support shall be extended to farmers who keep trees on their fields, with a view to the negative, short-range effects TOF are capable of having on crops, due to shading, root competition (Górka 1989), pest hosting (Puszkar 1981), ground littering or growth season shortening being compensated for.

THE SERVICES PROVIDED BY TREES OUTSIDE FOREST

Long-term research conducted by several scientific centres (the Institute for the Agricultural and Forest Environment, Institute of Soil Science and Plant Cultivation, Lublin Agricultural University, Forest Research Institute) has recognized and evaluated diverse services and products offered by woody patches and belts in agricultural landscapes.

The large-scale capabilities of TOF to mitigate stress in the environment, which are hardly matched by any technical means, relate to water and nutrient cycling (transpiration, runoff and percolation, Ryszkowski and Bartoszewicz 1989, Prusinkiewicz *et al.* 1990), the combating of water contamination (Szajdak *et al.* 2002) and soil erosion caused by water and wind (Józefaciuk and Józefaciuk 1999), as well as biodiversity conservation and the enhancement of crop pollination. Trees and shrubs may also be used locally to substitute artificial structures (fences, barriers against advection frosts and traffic-caused noise and air pollution, shadowing or obscuring curtains, snow catchers, escarpment reinforcements and decorations), adding to these extra effects of enhanced biodiversity, live decoration, accelerated soil forming process and lower building and carbon costs of structure production and installation.

Positive effects of TOF extend across property boundaries and ecosystems, enhancing production stability, biodiversity and local community welfare. As means of environmental hazard control and rural development, new TOF planting projects may be included in spatial planning processes (Zajączkowski 1989, Ryszkowski and Bałazy 2003) and financed publicly (Jankowiak 2010, Zajączkowski and Zajączkowski 2009), though this is currently a rare practice due to local budget limitations.

The carrying out of potential services analysis prior to any new planting of TOF optimizes results within the framework of limited resources. Procedures for analysis of this kind were proposed by Zajączkowski (2005), in a concept concerning the needs of agricultural landscapes as regards afforestation, which is deemed relevant to the ecosystem services offered by TOF. Two general categories of afforestation need were distinguished: (i) the limiting of large-scale environmental threats and (ii) the fulfilment of local community demands for services and goods. The main objective is to optimize the structural features of new TOF plantings in line with regional needs recognized. The areas of urgent afforestation needs, in which a loss of crop production due to environmental problems is observable currently, account for almost 50% of Poland, albeit located mostly in the central lowlands and southern uplands.

Information on large-scale negative environmental processes (relevant to the area of a single gmina, or larger) and different local-community demands may be extracted from published sources: topographic and thematic maps, aerial imagery and statistical tables. The data *i.a.* concern soil water and wind erosion classes, water deficit, levels of contamination of surface and ground waters, water source areas, the density and length of biologically active landscape structures (forests, TOF, extensive meadows and pastures, buffers and wastelands), the limits of planned areas of afforestation, the locations of sources of air pollution and noise (roads, livestock farms and processing plants), frost-sensitive and bee pollination-dependent crops, snowbank forming places along roads, farm buildings frozen by cold winds, recreation areas, public places in which additional decoration or emphasis by woody vegetation is needed (historical monuments, isolated chapels, shrines or graves, bus stops, parking places, schools and health centres), etc. Supplementary field investigations and interviews with local representatives might be necessary if specific information on certain environmental problems and social preference is to be obtained. Table 1 gives an example list of local needs as regards afforestation, and the parameters used in identifying them.

The important, but currently underemphasized products of TOF systems are firewood and sawnwood. The volume of the utility timber cut outside forests in Poland is of about a million m^3. (2013 Statistical Yearbook), or the equivalent of 3% of that cut from forested land. However, due to better growing conditions, the annual growth in timber volume for TOF was an estimated 6% of that achieved in forests. Poplar or willow clones, grown in full light on rich soils, may achieve heights of 30 m and average annual volume growth of 20 m^3 per hectare. This is respectively 30% and 100% more than the capabilities of native forest species, especially larch and birch (Zajączkowski 2005).

Table 1. Examples of afforestation needs of agricultural landscapes in Poland and the parameters used in their local identification (after Łonkiewicz *et al.* 1993)

Afforestation need (ecosystem service from TOF)	Identification Parameters
Enhancing capability of ecosystem to retain water	Water balance in growing season below –100 mm. Forest area share below 30%.
Decreasing evapotranspiration on arable land	The presence of desiccation-prone soils over a contiguous patch larger than 10 ha.
Counteracting soil erosion caused by rainwater	The presence of rendzina or loess soils on slopes with an inclination of 6° or more. The presence of loamy or sandy soils on slopes with an inclination of 10° or more.
Counteracting soil erosion caused by wind	The presence of loose soils over a contiguous patch larger than 10 ha. Share of all arable land accounted for by loose soils exceeding 25%.
Counteracting contamination of surface waters by fertilizers and pesticides	The presence of farmland slopes with an inclination of 5° or more in the direction of a river, stream, drainage ditch, lake or pond. A lack of artificial embankments.
Enhancing biodiversity	Forest area share below 15%. Farmland area share over 80%. Arable land share in overall farmland area exceeding 75%.
Timber production	Forest area per capita below 0.2 ha. Firewood sales deficiency in local Forest District.

STRUCTURAL AND SPATIAL RECOMMENDATIONS FOR NEW PLANTINGS

Practical experiments and observations suggest that significant relationships exist between the capabilities of TOF to mitigate different environmental hazards and their structural properties and location. Available suggestions on TOF best species composition, final tree height, lower layer presence, crown density, shelterbelt width, patch spatial dispersion and topographic location were reviewed by Zajączkowski *et al.* (2001), Zajączkowski (2005), Bałazy (2002) and Zajączkowski and Zajączkowski (2009, 2013). Among the most important of these is the suggestion that only large-scale systems of shelterbelts or windbreaks may effectively mitigate wind, soil erosion and biodiversity loss effectively, with subsequent parallel belt distance varying from 200 to 500 m, depending on the type and severity of problems, and soil properties. Wider belts or ones containing coniferous species were found to be necessary where the mitigation of wind-caused problems occurring outside the growing season was concerned. To make the zone of lowered wind speed wider, vertical crown densities

(observed horizontally) should not exceed 70%, this enabling air flows to enter crown interiors and lose their energy in turbulence. The net-type spatial structures of TOF should be formed to ensure the diversity and vitality of animal and plant populations (Kujawa 2002, Kujawa and Kujawa 2008, Ryszkowski *et al.* 2002), as well as the effective control of crop pests. Such structures should be composed of many wild tree and shrub species, including fruit-bearing and thorny ones, and should contain sunny, uncultivated patches of soil for wild bees and spiders, as well as habitation by other pollinating or pest-controlling species.

FUTURE LIMITATIONS AND PROSPECTS

On average, only 25% of farms in Poland cover more than 15 ha. It is usual for the smaller farms, which still therefore prevail, to have higher densities of linear structures (e.g. field or road boundaries) appropriate for tree planting. However, decisions on TOF establishment may be more difficult for smaller farm owners, because on narrow field strips or small patches the losses of field area and negative impacts in the immediate vicinity of trees may overcome potential benefits to crops. Financial incentives for keeping trees on fields such as "ecological focus areas" (EFAs) have been proposed lately as part of 'greening' regulations within the EU Common Agricultural Policy framework. However, as farms of less than15 ha were excluded from them, the aid will eventually extend to less than 50% of total farmland area, with a consequent limitation of the role in mitigating wind-related hazards.

Given current forecasts for future climate (IPCC 2014), groundwater loss due to increased summer temperatures, wind speeds and decreased snow cover are expected to be important factors affecting crop yields in Polish agriculture (Ostrowski *et al.* 2009). Although climate change mitigation is among the goals of the aforementioned 'greening', new regulations are generally biodiversity-oriented and do not promote spatial systems of trees or vertical structures that would prevent water loss and soil erosion due to wind.

A preliminary set of structural indicators for TOF which might be incorporated into future EFA requirements and payment calculations was proposed by Zajączkowski and Zajączkowski (2009).

New legislation is recommended to make afforestation needs analysis an obligatory part of regional and local spatial management plans for areas with significant environmental problems (urgent afforestation needs). Under this condition, projects for new TOF planting concordant with spatial management might be supported using public funds.

Future carbon sequestration capability of TOF is assessed as 10% of that of forests (Zajączkowski 2005), on condition that fast growing species (poplar and willow clones) are maintained within the species composition of new planting of TOF. Offering 3 million m^3 of potential annual timber production (three times the current level),

enlarged and structurally redeveloped areas of TOF would contribute significantly to policy to achieve goals as regards carbon sequestration that the Polish Government is committed to under the Kyoto Protocol.

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