Forest Ecology and Management 413 (2018) 76–89

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Anthropogenic linear gaps in managed forests – Plant traits are associated with the structure and function of a gap

Katarzyna M. Zielińska[a,*], Marcin Kiedrzyński[a], Damian Chmura[b]

[a] Department of Geobotany and Plant Ecology, Faculty of Biology and Environmental Protection, University of Lodz, Banacha Str. 12/16, 90-237 Łódź, Poland
[b] Institute of Environmental Protection and Engineering, University of Bielsko-Biala, ul. Willowa 2, 43-309 Bielsko-Biała, Poland

ARTICLE INFO

Keywords:
Plant diversity
Forest roads
Drainage ditches
RLQ ordination
Fourth-corner method

ABSTRACT

The impact of anthropogenic linear gaps (such as roads, paths, and drainage ditches) on the diversity and other features of the flora of managed forests is still poorly studied. The main aim of our study was to analyse the plant trait responses to the presence of drainage ditches and forest roads. These two kinds of anthropogenic gaps differ in their structure (microtopography) and function. The functional traits of species in plots containing different anthropogenic linear gaps were compared with those in plots without such gaps inside surrounding forests. The floristical composition of 838 plots was analysed by RLQ ordination followed by fourth-corner analysis. Both drainage ditches and forest roads were characterised by a significantly higher number of species than the surrounding forests. However, they differed with regard to their functional traits. The presence of a road was positively associated with occurrence of plants whose propagules are dispersed by wind, water or by transportation on the outside of vertebrate animals, as well as with occurrence of species that have upward dynamic tendencies in a number of localities in the country scale. The floristic composition of plots lying inside the forests was also associated with the same traits but the relationship was reversed. By contrast, ditches did not show any associations with species traits. The influence of linear gaps on the pattern of species functional traits depends on the degree of habitat diversification associated with a given structure and whether its functioning involves the movement of people and vehicles.

1. Introduction

Anthropogenic linear gaps (ALG) such as roads, trails, power lines, railways and ditches are common elements of the landscape of forest complexes in the Anthropocene era. A linear gap can function as a source of new habitats for a large group of plant species, thus influencing the floristic diversity of the whole area (Peterken and Francis, 1999; Smith et al., 2007; Suárez-Esteban et al., 2013a; Staniaszek-Kik et al., 2016). Two main attributes of great ecological importance are shared by such structures. The first is the openness in the tree canopy, which causes a change in light and microclimatic conditions (Gálhidy et al., 2006), the second is the great length compared to their width, which effectively turns them into ecological or disturbance corridors (Watkins et al., 2003; Suárez-Esteban et al., 2013a).

Openness in the tree canopy can be favourable for light-demanding species, which are sometimes ecologically alien to forest communities or whose presence represents the stand-disturbance phase of the long-term dynamics of a forest stand (Peterken and Francis, 1999; Gálhidy et al., 2006). Gaps in forest canopies have always been widespread in European temperate forests as a part of age-induced stand dynamics and as a consequence of local fires or windstorms. For centuries, the use of traditional models of forest management also resulted in the occurrence of tree-stand openness. Nowadays, for economic reasons, relatively young and dense stands are maintained in forestry, which may cause a loss of biodiversity, especially a loss of the light-demanding species (Franklin et al., 2002). In this context, anthropogenic linear gaps can sometimes function as refuge habitats for such species, including rare and endangered ones (Smith et al., 2007; Catling and Kostiuk, 2011; Zielińska et al., 2016). Therefore, anthropogenic openness in tree canopy can be favourable for species diversity (Peterken and Francis, 1999; Smith et al., 2007; Zielińska et al., 2016; Suárez-Esteban et al., 2016). However, the linear character of the structures is usually regarded as unfavourable from a conservationist point of view, and not only because the linear gaps cut contemporary forest ecosystems into smaller fragments (Forman et al., 2003; Trombulak and Frissell, 2000): Such structures allow the creation of habitats appropriate for expansive, cosmopolitan and hemerophilous plants, and these can constitute migration routes for alien species (Godefroid and

* Corresponding author.
E-mail addresses: katarzyna.zielinska@biol.uni.lodz.pl (K.M. Zielińska), marcin.kiedrzynski@biol.uni.lodz.pl (M. Kiedrzyński), dchmura@ath.bielsko.pl (D. Chmura).

https://doi.org/10.1016/j.foreco.2018.02.001
Received 11 October 2017; Received in revised form 11 December 2017; Accepted 1 February 2018
Available online 13 February 2018

Koedam, 2004; Parendes and Jones, 2000; Buckley et al., 2003; Watkins et al., 2003). Therefore, despite the relatively high species richness of ALG, their presence can have far-reaching effects and substantially reduce the natural biodiversity of a given region (van der Ree et al., 2011). The ambiguity of the role of anthropogenic linear gaps is, among others, an effect of the diversification of these structures (Baltzinger et al., 2011; Zielińska et al., 2013).

The function of ALG in a forest complex can be described as twofold: altering habitat conditions (the abiotic and biotic features of the site) and serving as a movement path for plant propagules (Trombulak and Frissell, 2000). It can be assumed that both of these factors should be reflected in species functional traits. A plant functional trait approach is useful for the study of patterns and processes that underlie vegetation changes (Bernhardt-Römermann et al., 2011; McIntyre et al., 1999). It can also be used for identifying potential mechanisms underlying variation in the distribution and abundance of species (Mabry et al., 2000).

Our study analyses plant functional traits associated with the two types of anthropogenic linear gaps: forest roads (the ones of minor transport importance, used primarily by the forest services) and drainage ditches. Generally the analysed roads and ditches displayed two distinct features. The first was connected with their microtopography: Forest roads with their narrow and flat roadsides provided rather small irregularities of ground evenness, while ditches, with their deeper bottoms and two slopes, provided substantial topographical disturbance. The second general difference between the analysed structures was connected with their purpose. Both are human-made corridors fulfilling transport functions; however, while roads are used for the transport of people and vehicles, drainage ditches were dug for the transport of water. The presented study does not only examine whether sites connected with these ALG favour the occurrence of specific functional traits: the incorporation of the two structurally and functionally different types of ALG into the study provides an insight into the determinants of their ecological role in managed forest, other than light accessibility conditions, which are common for all ALGs. Light accessibility could be excluded from the comparison because roads and ditches of similar widths were sampled. We could hypothesize that if it is the linear feature of ALG that is of the greatest importance for their functioning in forest ecosystems, the results obtained for the two analysed ALG types should have a similar outcome. Conversely, if the other features shared by the ALG have comparable or greater significance, it is reasonable to assume that the results would vary. As linearity is usually associated with the facilitation of species migration, our study focuses on plant traits which are important from the point of view of species propagation and spreading.

The main goal of our study was to determine the importance of the linear anthropogenic gaps in managed temperate forests for creating specific spectra of plant functional traits. The second aim was to broaden our understanding of the role played by the topography of ALG, and the form of transport associated with them, in the creation of the mentioned spectra.

2. Materials and methods

2.1. Field research

The research was conducted in managed forests in Central Poland (the Central European Lowlands) between 2009 and 2014 in July and August (Fig. 1a). The study area is situated in the transitional zone between suboceanic and continental climates with an average temperature of 9 °C and precipitation of 550 mm. The bedrock of the local soils is predominantly Pleistocene sands and clays.

The forest stands in the studied complexes primarily consist of *Pinus sylvestris*, planted on sites where the natural potential vegetation is mostly subcontinental pine-oak forests and suboceanic pine woods (Matuszkiewicz, 2008). Besides Scots pine, the stands are home to broadleaf trees including birch (*Betula pendula*, *B. pubescens*), oak (*Quercus robur*, *Q. petraea*), hornbeam (*Carpinus betulus*), beech (*Fagus sylvatica*), maple (*Acer pseudoplatanus*). Two alien taxa were also noted: *Quercus rubra* and *Robinia pseudoacacia*. The studied forest complexes are crossed by relatively wide ditches and a series of small roads, the majority of which are dirt roads used by foresters. This arrangement allowed a number of roads and ditches of similar width to be incorporated into our studies, thus avoiding a situation in which width is a variable that differentiates ALG.

Eleven transects, each consisting of a series of adjacent rectangular plots (1 × 5 m), were delineated within the five forest complexes (Fig. 1b). The randomness of a sample of forest roads and ditches was ensured by the nature of transect delineation. The researchers entered the forest by a randomly-chosen road and moved until the presence of the drainage ditch was confirmed in the area. A transect line was set up to cross the road and the ditch. If this line intersected more roads and ditches on the route, the transect was extended as far as it was justified; for example, if it approached the neighbourhood of the forest edge or other structures not covered by the study. The transects ran at least 500 m from any anthropogenic disturbances that are not covered by the present analysis, such as areas of tree falling or young plantings. As all adjacent plots forming the transect were included in the analysis, the number of plots in each transect varied from 32 to 273, depending on local conditions. The transects intersected roads and ditches which showed no traces of any conservation work such as vegetation removal or ditch deepening; On the contrary, the studied vegetation appeared to have been spontaneously formed over at least a dozen years without any significant disturbances.

The transects intersected ALG of various widths; however, none were wider than six metres. Although the narrower anthropogenic structures (narrower than 0.5 m) do not really form gaps in the forest canopy, they do nevertheless have a linear character and can substantially affect the species composition of plant communities (Hamberg et al., 2008); therefore, they were not removed from the analysis, but were separated into distinct categories of small ditches and paths. In this way, the ALG were divided into small ditches, ditches, as well as paths, roads and roadsides (Fig. 1b, Table 1). The last two categories were necessary as the significance of species-rich patches of the roadsides would be reduced by treating the roads as homogeneous systems, i.e. by incorporating these habitats into the same category as the hardened parts of roads, where the floristic richness was actually zero. As controls, we used plots lying within the tree-stand: these were named ‘forest plots’. By taking a large sample of these plots, coverage was ensured of all possible types of forest sites, i.e. those lying directly under the tree crowns of different species and between them.

In each plot, the percentage of particular ALG types was evaluated, also the vascular plant species growing in the herb- and shrub-layer were listed together with their cover. Coverage of species was estimated according to the following scale: 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100%. The tree species whose crowns spread over the studied plots were also noted, and these were used to recognise the characteristic attributes of the plots.

2.2. Data analysis

To examine the relationships between the species traits and the environmental characteristics of the research plots, an RLQ ordination