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The impact of forest infrastructure reconstruction on expansion of potentially invasive plant species: First results from a study in Latvia

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Abstract

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Today, when anthropogenic pressure on natural ecosystems promotes degradation of natural habitats and facilitates distribution of alien species, local disturbances such as forest management become more significant in relation to alien plant species expansion. The aim of this study was to investigate the impact of forest road and drainage network reconstruction on the vegetation composition focusing on the expansion of invasive alien plant species. The occurrence and coverage of vascular plant and bryophyte species were recorded within 160 sample plots along four forest roads and four drainage ditches. This paper summarises the first results of this study. The main results indicate that small-scale linear corridors like forest roads and drainage networks can promote the expansion of invasive alien plant species.

Keywords: forest management; forest roads; forest drainage network; species richness

The distribution of invasive plant species is considered to be an indicator of the stability of biota and biodiversity (Weber, Gut 2004), as the proliferation of invasive species can alter local ecosystems and their functions, as well as degrade biota and cause economic losses (Pimental et al. 2000). Invasive plant species often decrease the diversity of local plant species (Powell et al. 2011) and alter the nutrient cycling rates (Ehrenfeld 2010), thus influencing ecosystem services and human well-being (Pejchar, Mooney 2009). Alien plants have significant impacts at the species, community and ecosystem level (Vilà et al. 2011) but current understanding of the impacts is often restricted to relatively few dominant species (Pyšek et al. 2008).

Invasive species are mainly distributed near urban areas, transport corridors (Von der Lippe, Kowarik 2007) and watercourses (Wilczek et al. 2015). In forest ecosystems, forest edges have been recognised as the first places to be colonised by invasive plant species (Pauchard, Alaback 2006) and the main pathways of the spread of invasive species are forest roads and streams (Tyser, Worley 1992; Parendes, Jones 2000; Priede 2009), forming habitats for invasive plants (Von der Lippe, Kowarik 2007). Colonization by invasive species is affected by disturbances, as well as by the intensity of forest

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management and utilisation of forest infrastructure (With 2002; Pauchard, Alaback 2006).

In Latvia, the regulations determine only one species *Heracleum sosnowskyi* Mandenova as invasive (Cabinet of Ministers Regulation No. 468, 2008). However, 36 plant species are also considered potentially invasive (Nature Conservation Agency 2018), yet the majority of these species have been spreading slowly and have not been aggressive, although intensification of forest management might facilitate their spread in Latvia (Priede 2009). Nonetheless, scarce information is available concerning species invasion directly after disturbances.

The aim of this study was to assess the floristic composition of forest infrastructure before and immediately after reconstruction of forest roads and drainage ditches focusing on expansion of potentially invasive alien plant species. This paper introduces and presents the first results of the initiated long-term observation.

MATERIAL AND METHODS

Study sites and observations. The study was conducted in the Central part of Latvia (56°21'29''N; 25°13'17''E) in a managed state forest district with an area of 2,762 ha located near village Zalve. The area is mostly covered by conifer stands with admixture of broadleaves on mesotrophic mineral soils, part of which were drained for forestry in the second half of 20^{th} century. The closest village, Zalve, is located 7 km from the study area. Within the catchment, there are ruins of a dwelling, located less than 1 km from the transects. Reconstruction of all forest roads under survey was carried out according to "business as usual" principles in line with the guidelines of the State Forest Management company. First, the tree vegetation (including stumps) was removed from the routes of the roads and ditches. After that the cleaning of ditches and roadside ditches, construction of infrastructure elements (e.g., culverts), flattening of surface and restoration of the gravel cover on the roads was carried out. The species *Festuca rubra* Linnaeus and *Lolium* sp. have been seeded along the roads.

Long term vegetation survey plots were established along: (*i*) one forest road reconstructed in the last year, (*ii*) two old forest roads on natural base to be reconstructed next year, (*iii*) one road to be constructed (marked route in forest), (*iv*) two drainage ditches renovated last year, (*v*) two old (edges covered with large trees) drainage ditches under renovation. Summarizing, two roads at the time of the survey were considered as unmanaged, one – marked road, one managed road, two ditches – managed, two ditches – unmanaged. At each site, vegetation survey was performed along a 1-km long section of the road or ditch. In each section, 10 transects were established with 100 m spacing, and perpendicular to the road or ditch (Fig. 1). Each transect was divided into two 3 × 10 m plots on the left and right sides of road or ditch (Fig. 1). In total, 160 plots were established. In each plot, the total cover of all vascular plant and bryophyte species and the cover of each species were recorded according to Braun-Blanqet (1964) method, using five scales. Vascular species nomenclature given by Gavrilova and Šulcs (1999) and that by Āboliņa et al. (2015) for bryophytes was used. Vegetation surveys were conducted from June to July 2016.

Invasive and potentially invasive species were determined according to the methodology and criteria developed by the Nature Conservation Agency of Latvia, within the scope of several national and international projects (Nature Conservation Agency 2018).

Data analysis. To describe environmental conditions of each plot, Ellenberg's indicator values (Ellenberg et al. 1992) based on occurrence of all species within a plot were calculated. For each object type, detrended correspondence analysis (DCA) was used to assess ecological gradients present within vegetation data and to relate them with Ellenberg's indicator values. To assess the differences in species richness (number of species) per plot (both sides of the road or ditch) (Fig. 1) among the different type of object management (old or reconstructed road, marked route in forest, renovated or old drainage ditch), generalised linear models (GLM) were applied. In all cases, Tukey's honest significant difference post-hoc test was applied to compare the levels of the factors. The differences in the occurrence of invasive species in relation to type of object management were assessed by GLM. In all cases, a Poisson residual distribution and log link (Zuur et al. 2007) were used.

Species composition among different types of objects and types of management were compared us-

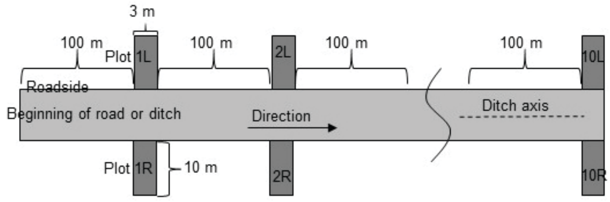

Fig. 1. Vegetation inventory on forest roads and drainage ditches

L – left side of road, R – right side of road ing analysis of similarities, where a similarity index of $R = 1$ indicates diversity between areas, whereas $R = 0$ indicates random grouping. All analyses were conducted at the significance level $\alpha = 0.05$. The DCA was done in PC-ORD (Version 6, 2011) (Peck 2010), other analyses were performed in R software (Version 3.1.2, 2017) using the "vegan" package (Version 2.5-2, 2017) for analysis of similarities and the "multcomp" package (Version 1.4-8, 2017) (Hothorn et al. 2008).

RESULTS AND DISCUSSION

Number of species

In total, 249 vascular plant species (and tree species at herbaceous layer) and 42 bryophyte species were recorded. The greater number of species found along ditches can be explained by the large number of hydrophyte and graminoid species on ditch banks. Along roads, a large number of annual, biannual and ruderal species were observed. The number of species present was related to object type, as significant differences ($P < 0.001$) between types of object management were observed (Table 1).

The smallest number of species per plot was observed along reconstructed roads. Variations in the number of species in this transect (from 1 to 34 species in one plot) indicated that the rate of species introduction after management was related to many different factors (Table 1). The number of species along both old and newly-renovated drainage ditches was higher than along roads (Table 1), indicating more varied growing conditions. The total number of species along old drainage ditches (180) and ditches renovated one year ago (106) was much higher than that found along any type of road (168), indicating that the renovation of ditches could cause less disturbance to a habitat than does the construction of roads.

Potentially invasive plant species

In total, four potentially invasive plant species – *Lupinus polyphyllus* Lindley, *Solidago canadensis* Linnaeus, *Rumex confertus* von Willdenow and *Conyza canadensis* (Linneaus) Cronquist (Nature Conservation Agency 2018) – were recorded on four of eight transects, and only one species per transect was observed in each case. It is very likely that some of these species have been established from nearby populations. For example, the distribution map of *L. polyphyllus* has shown its abundance near the study territory (Priede 2009). The invasion of *L. polyphyllus* was considered to be relatively high comparing with other determined invasive species. It was found throughout the whole transect length and occupied up to 50% of the total cover. However, large number of other non-invasive and non-ruderal species was recorded in the plots with *L. polyphyllus*. The results from following years will show whether biological value of the site will be reduced due to invasive species. Currently it is also difficult to conclude after first year results whether the species richness is higher in disturbed areas, as mentioned in literature (Hobbs, Huenneke 1992; Laiviņš, Gavrilova 2009).

Although *S. canadensis* is considered to be one of the most aggressive and widespread alien species throughout Europe (Jakobs et al. 2004), in this study, several individuals of this species were found in only four plots along one renovated drainage ditch. This may be due to interspecific competition and limited light availability in undisturbed plots along old drainage ditches or marked route in forest (existing tree cover); however, Priede (2009) indicated that *S. canadensis* and *R. confertus* may spread well in a forested area with a dense network of forest roads, drainage ditches or streams. In our study, *R. confertus* was recorded in eight plots along two drainage ditches. Although presently its cover was below 5% within a plot, anthropogenic activities may promote its spreading in riparian and humid

Table 1. The number of species in plots of different management and land use types. The *P*-value (Tukey's honest significant difference) indicates the differences between reference and other levels

Type of object management	No. of plots	No. of species			*P*
		mean ± SE	minimum	maximum	
Forest road with natural base (intercept)	40	18 ± 1.05	7	36	
Marked road route in forest	20	15 ± 1.68	5	35	0.002
Reconstructed road	20	15 ± 1.99	1	34	0.001
Old drainage ditch (intercept)	40	35 ± 1.06	21	46	
Renovated drainage ditch	40	41 ± 1.06	27	57	< 0.001

SE – standard error

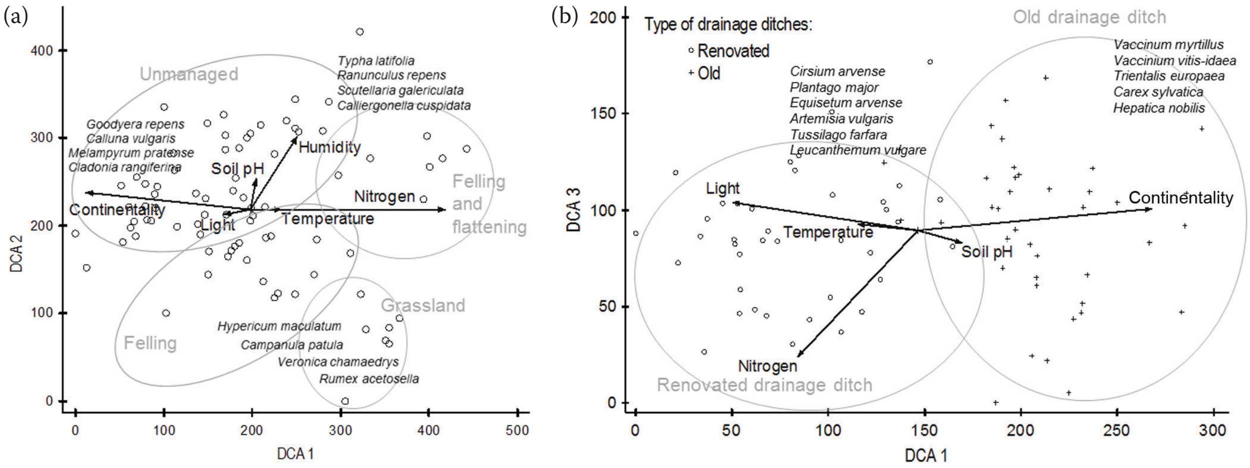

Fig. 2. Detrended correspondence analysis (DCA) ordination of forest road plots by management regime (a), drainage ditch plots (b). Distributed groups are illustrated with grey ellipses. Arbitrarily selected (based on graphical inspection) group-specific species are indicated

habitats, so the invasion of *R. confertus* may potentially increase over the next few years. Although in Latvia *C. canadensis* most commonly spreads along transport corridors (Priede 2009), the authors of this study observed separate plants along two renovated drainage ditches, where the disturbance had created open land conditions. None of the invasive species typical for river valleys in Europe, such as *Impatiens glandulifera* Royle, *Echinocystis lobata* (Michaux) Torrey & A. Gray and *H. sosnowskyi* (frequently occurring in Latvia), were recorded in the studied area, indicating that the territory remains isolated, and the existing hydrographic network within it currently does not facilitate the invasion. In the following years of the study, the results will show whether the presence of invasive species in the studied area will have a negative impact on species richness and abundance on a catchment scale.

Species composition and grouping

The DCA of road and drainage ditch plots indicated a high influence of disturbance and environmental conditions created by management on species composition. Species composition significantly differed ($R = 0.59$, $P = 0.001$) between plots along forest roads and drainage ditches, indicating that different plant communities are formed after disturbances. This is mainly explained by local factors – forest characteristics and soil differences in the vicinity of infrastructure objects. The potentially invasive plant species did not form separate groups in the DCA. It may be explained by the fact that the cover of each determined invasive species was low and they were not dominant in almost none of the sample plots.

In the DCA of road plots, four groups management activities were distinguished (Fig. 2a). Most of the plots were located in forest (with no visible management during last 10 years, referred to as unmanaged), with locations mainly determined by humidity conditions; therefore, both moisture- and drought-tolerant species were found in this group (Fig. 2a). The next group represented roadsides in harvested forests. A separate group was formed by plots situated in the small dry forest grassland, characterised by a variety of typical grassland species (Fig. 2a).

In DCA two groups of plots within drainage ditches were distinguished: old and renovated (Fig. 2b). Renovated ditch margins were characterised by higher amount of nitrogen, high light availability and thus also higher temperatures, forming a favourable environment for a variety of species that prefer open and ruderal habitats. In contrast, species preferring continental conditions and those mainly hemiboreal forest species were observed along older drainage ditches (edges with large trees; Fig. 2b). The distribution of invasive plant species clearly indicated the effect of forest infrastructure maintenance, as significantly more often ($P < 0.05$) invasive plant species were recorded along reconstructed drainage ditches. Nevertheless, invasive species were not more common ($P = 0.12$) on the soil banks.

CONCLUSIONS

Maintenance and construction of forest infrastructure have impact on the expansion of invasive plant species, as more often invasive species are found in plots along reconstructed roads and ditches. As demonstrated by the example of *L. polyphyllus*, as soon as an invasive species has reached its potential growth site, it may spread along the recently reconstructed road. While no invasive species were found along old forest roads and along old drainage ditches, a few of these species were recorded along newly-reconstructed roads and renovated ditches, that could indicate that a network of roads, drainage ditches and other linear objects, as well as intensive management, can favour species invasion. Whether or not the expansion of the invasive plant species continues in the years following the forest infrastructure construction, and what pathways of spreading exist, remains to be investigated in further phases of this study.

References

Āboliņa A., Piterāns A., Bambe B. (2015): Lichens and Bryophytes in Latvia, Checklist. Salaspils, DU AA "Saule": 213.

Braun-Blanqet J. (1964): Pflanzensoziologie. Grundzüge der Vegetationskunde. Wien, Springer-Verlag: 865.

Ehrenfeld J.G. (2010): Ecosystem consequences of biological invasions. Annual Review of Ecology, Evolution, and Systematics, 41: 59–80.

Ellenberg H., Weber H.E., Düll R., Wirth V., Werner W., Paulissen D. (1992): Zeigerwerte von Pflanzen in Mitteleuropa. Scripta Geobotanica No. 18. Göttingen, Goltze: 258.

Gavrilova G., Šulcs V. (1999): Flora of Vascular Plants of Latvia. List of Taxa. Rīga, Latvijas Akadēmiskā bibliotēka: 136. (in Latvian)

Hobbs R.J., Huenneke L.F. (1992): Disturbance, diversity, and invasion: Implications for conservation. Conservation Biology, 6: 324–337.

Hothorn T., Bretz F., Westfall P. (2008): Simultaneous inference in general parametric models. Biometrical Journal, 50: 346–363.

Jakobs G., Weber E., Edwards P.J. (2004): Introduced plants of the invasive *Solidago gigantea* (Asteraceae) are larger and grow denser than conspecifics in the native range. Diversity and Distributions, 10: 11–19.

Laiviņš M., Gavrilova G. (2009): Biogeographical analysis of vascular plant flora in Ventspils and Daugavpils cities. Latvijas Veģetācija, 18: 25–79. (in Latvian)

Nature Conservation Agency (2018): Invasive species. Available at https://www.daba.gov.lv/public/lat/dabas_aizsardzibas_plani/dati1/invazivas_sugas/ (accessed July 20, 2018). (in Latvian)

Parendes L.A., Jones J.A. (2000): Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. Conservation Biology, 14: 64–75.

Pauchard A., Alaback P.B. (2006): Edge type defines alien plant species invasions along *Pinus contorta* burned, highway and clearcut forest edges. Forest Ecology and Management, 223: 327–335.

Peck J.E. (2010): Multivariate Analysis for Community Ecologists: Step-by-step Using PC-ORD. Gleneden Beach, MjM Software Design: 162.

Pejchar L., Mooney H.A. (2009): Invasive species, ecosystem services and human well-being. Trends in Ecology & Evolution, 24: 497–504.

Pimental D., Lach L., Zuniga R., Morrison D. (2000): Environmental and economic costs of nonindigenous species in the United States. BioScience, 50: 53–65.

Powell K.I., Chase J.M., Knight T.M. (2011): A synthesis of plant invasion effects on biodiversity across spatial scales. American Journal of Botany, 98: 539–548.

Priede A. (2009): Invasive neophytes in the flora of Latvia: Distribution and dynamics. [Ph.D. Thesis.] Riga, University of Latvia: 127. (in Latvian)

Pyšek P., Richardson D.M., Pergl J., Jarošík V., Sixtová Z., Weber E. (2008): Geographical and taxonomic biases in invasion ecology. Trends in Ecology & Evolution, 23: 237–244.

Tyser R.W., Worley C.A. (1992): Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conservation Biology, 6: 253–262.

Vilà M., Espinar J.L., Hejda M., Hulme P.E., Jarošik V., Maron J.L., Pergl J., Schaffner U., Sun Y., Pyšek P. (2011): Ecological impacts of invasive alien plants: A meta-analysis of their effects on species, communities and ecosystems. Ecology Letters, 14: 702–708.

Von der Lippe M., Kowarik I. (2007): Long-distance dispersal of plants by vehicles as a driver of plant invasions. Conservation Biology, 21: 986–996.

Weber E., Gut D. (2004): Assessing the risk of potentially invasive plant species in Central Europe. Journal of Nature Conservation, 12: 171–179.

Wilczek Z., Chabowska Z., Zarzycki W. (2015): Alien and invasive species in plant communities of the Vistula and Brennica rivers gravel bars (Western Carpathians, Poland). Biodiversity Research and Conservation, 38: 57–62.

With K.A. (2002): The landscape ecology of invasive spread. Conservation Biology, 16: 1192–1203.

Zuur A., Ieno E.N., Smith G.M. (2007): Introduction to mixed modelling. In: Analyzing Ecological Data. New York, Springer-Verlag: 125–142.

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