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Investigation of the invasive plant infestation of the railway line between Gödöllő and Hatvan

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Abstract: Railway systems are considered as a special environment and they can play a key role in the spread of the invasive plant species. In Hungary, there was no survey that specifically examined the importance of these linear facilities before. Our survey aims to examine the condition of the Gödöllő-Hatvan railroad line in terms of the levels of invasive plant-infection and what can be the role of the railway itself in it. The data were collected manually by walking along the entire examined railway track section, where the invasive species were recorded within the 10 meter range of the outer axis of the open railway track. The latter was divided into 30 one-kilometer long sections and 120 two hundred and fifty meters long subsections. The exact position of each invasive species was recorded in these (sub)sections. The surveyed area was very diverse in habitat types. In the present study, the spatial distribution of the most common species is also presented in the studied trajectory section, highlighting the most infected areas. Contrary to our preliminary idea, the latter did not always occur in the immediate vicinity of the settlements. The survey did not demonstrate that this railway line promotes the spread of all occurring invasive species probably due to the very diverse habitats but for a general conclusion the study should be extended both in space and time.

Keywords: Invasive plants, railway main line, invasive plant-infection, abundance, spatial pattern

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Introduction

Invasive species are causing serious problems today in Hungary as well as nearly in the whole world. There are ecosystems without invasive species infections. Invasive species tend to make negative impacts on the environment even if it is artificial or natural (or semi-natural). These species can make an effect in the nature conservation and agricultural areas, and can be a threat for human health as well (for example *Ambrosia* & *Solidago* species) (Csiszár et al. 2012). Most endangered areas are the islands, in an ecological sense too, and the areas being some way geographically and ecologically separated ecosystems, because they have low if any resistance against newly introduced species. It is hard to find an exact definition for invasive species because almost all nations/governments have their own, but it is agreed by most definitions that invasive species are 1) non-native to the given ecosystem, and 2) their introduction on the new ecosystems cause negative effects. The EU Regulation 1143/2014 on Invasive Alien Species defines it as “Invasive Alien Species (IAS) are animals and plants that are introduced accidentally or deliberately into a natural environment where they cannot be normally found, with serious negative consequences for their new environment.” In the original document this definition is even more specified with several points by which these species are defined further.

There are approximately 12000 non native plant species throughout Europe, and 10–15 percent of it can be recognized as invasive. In Hungary, more than half of the natural and semi-natural habitats are endangered by invasive species. Most sensitive areas are open sand steppes, floodplains and aquatic habitats (Varga et al. 2016). Besides the destruction of the habitats their fragmentation contributes significantly to the declining species diversity. Ecological and green corridors are elements of the environment and landscape which connects the fragmented habitats, thereby counteracting the fragmentation effect. These corridors' connecting effect can not only be positive, it also can be negative since it can assist the spreading of the harmful species. Corridors can be the natural or semi-natural watercourses, wave fields, roadside grassy areas, forest strips and man-made habitats like roads and railroads. (Bartha et al. 2004).

The specific edaphic & microclimatic conditions of the railway embankment, the herbicide treatments and the antropochoric nature of the propagules together determine the species compositions of the railway tracks. The railway tracks are special habitats, their structure is special: the roof of the substructure functions as a watertight layer, above it the crushed stone bed and the soles in it form the superstructure (Dancza et al. 2002, Bartha et al. 2004). The water management of the track bodies is extreme, they dry out regularly. Weeding of railway tracks is not just an aesthetic problem. Accumulating dry plant parts or other oily or nitrogen-rich wastes clog the bed, thus altering the drainage capacity, but the roots of the weeds can even damage the structure of the substructure (Sargent et al. 1984, Bartha et al. 2004).

Open track bodies are generally weed-free as a result of regular herbicide treatments. Giant and Canadian goldenrod (*Solidago gigantea*, *Solidago canadensis*), Bohemian knotweed (*Fallopia* ± *bohemica*), Boxelder maple (*Acer negundo*), Tree of heaven (*Ailanthus altissima*) and the False indigo bush (*Amorpha fruticosa*) are common on the slopes accompanying the railway sections (Bartha et al. 2004). A different herbicide treatment is used on the railway stations than on open road sections. The dominance of annual species can be observed at the stations. Most typical species are Bindii (*Tribulus terrestris*) and Common sandbur (*Cenchrus incertus*) (Dancza et al. 2002).

Linear facilities, including railways and their possible connection to the spread of alien species have already attracted the attention of several researchers. Some theories suggest that the Turkish wartycabbage (*Bunias orientalis*) in Britain found its way from England to Scotland among the rubble used for railway embankments (Sargent 1984). Altay et al. (2015) carried out their research in Turkey along railroads, that aimed to investigate the occurence of plant species in these areas. 20 non-native species were recorded of which three tree species (Boxelder maple, Tree of heaven, Black locust) are also registered as invasive in Hungary. There are proofs that urbanization has a positive effect on the settlement of these species, they have more occurence data at populated areas and stations (Altay et al. 2015). Rutkovska et al. (2013) in Daugavpils, Latvia, examined the importance of railways in the distribution of alien species, but not found close correlation, except for three species (*Dracocephalum thymiflorum, Erysimum durum, Lappula squarrosa*), which settled exclusively along railways (Rutkovska et al. 2013). Hansen & Anthony (2005) observed additional effects in a different way. It has been proved by transective studies that in forest vegetation the frequency of non-native tree species decreases with increasing distance from the railway, while that of herbaceous species does not show any perceptable change in the grasslands. The same effect along roads was studied by Flory & Clay (2005) for shrubs in the decidious forests of Indiana, USA. Christen & Matlack (2009) also investigated the role of roads in the spread of invasive species in South-East

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Ohio, U.S., and found that more invasive plant species occur along roads than in surrounding areas (Flory & Clay 2005, Hansen & Anthony 2005, Christen & Matlack 2009).

Important to highlight, for example, that *Robinia pseudoacacia* is one of the first trees from North America that has been imported to Europe (e.g. Ernyey, 1927; Kolbek et al., 2004; Vadas, 1914), as nowadays it means a serious threat to nature conservation and has a very high negative environmental impact (Kumschick et al., 2015). This species also very important economically, as it is a fast growing tree and considered to give very good quality timber, firewood, leaf forage and nectar. It also has very good use for erosion control, amelioration and as a shade giving and nurse tree (e.g. Gröhe, 1952; Kasper-Szel et al., 2003; Keresztesi, 1988; Papanastasis et al., 1998; Rahmonov, 2009; Rédei et al., 2008; Yüsek, 2012). Forman and McDonald (2007) and Mortensen et al. (2009) found that railway provide good habitat for invasive plant species for dispersal, as vehicles, wildlife and wind can move propagules along roads which can increase the range of invasive species (Forman and McDonald 2007, Mortensen et al. 2009).

To examine the importance of surrounding landscape, we highlighted *Asclepias syriaca, Robinia pseudoacacia, Solidago canadensis*. For *Asclepias syriaca* linear infrastructure elements can be an important habitat (Knight et al., 2019), especially on sandy soils (Bagi, 1999). *Robinia pseudoacacia* is a widespread invasive species throughout Hungary that causes many conservation problems (Kumschick et al., 2015). *Solidago canadensis* can be found in very dry locations and also waterlogged ones (Milo, 1993), in the vicinity of settlements (Botta-Dukát et al., 2008).

The aim of our research was the comprehensive survey of the invasive plant infestation of the railway section between Gödöllő and Hatvan. This area is currently under renovation, so this pre-renovation data collection will provide an opportunity to establish a long term study as well as future monitoring.

Our objectives include to 1) survey of the invasive plant-infestation of the abovementioned railway track section, 2) evaluation of the spatial pattern and frequency of invasive plant species occurring on the Gödöllő-Hatvan section, 3) making proposals for the treatment of invasive plant species in the longer term.

Materials and Methods

The field survey was conducted from June to October, 2017. The whole area was examined twice, to be sure of the invasive plant species composition. The entire examined Gödöllő-Hatvan railway line (30 kilometers) was divided into 30 one kilometer long sections, and further into 120 two hundred and fifty meters long subsections. The 250 meters subsections were important because it was the maximum area, that we could surely view and still has the ability to determine most of the species along the railroad after we walked along the section and noted the invasive plant species being present. This way we could examine 5 to 10 km sections in a day efficiently.

The 250 meters long subsections were further examined as 2,5 meter pieces, in which the presence of the invasive species were recorded within the 10 meter range of the outer axis of the open railway track. We could maintain this distance with measuring with a tape measure in every subsection. In the case of stations the outer range of the survey was up to a 10 meter distance from the outer borders of the stations. This method could provide numerical data in terms of frequency, which could be interpreted as percentage. The 10 meters distance was important due to the fact that most of the herbicide treatments and manual weeding is usually carried out in this range. Spraying along railway tracks takes place up to a distance of 3.2 meters from the center of the railway pair (Szarka, ex verb., 2021). Chemicals usually being glyphfozate, 2,4-dichlorophenoxyacetic acid, clopyralid, florasulam, fluroxipir-meptil, styrene-acrylic emulsion polymers, drometrizole trisiloxane, propylene glycol, carboxymethyl cellulose, metsulfuron-methyl, pethoxamid, terbuthylazine (http1). Beyond this limit there are usually forests, agricultural fields and artificial objects (e.g. roads, gardens, houses).

The following categories have been selected during the survey in relation to the frequency of each invasive species: I. 0–5%, II. 5–10%, III. 10–25%, IV. 25–50%, V. 50–75%, VI. 75–100%.

The sampling was carried out manually by walking along the entire examined railway track section (30 kilometers). The right and left sides of the sections were observed at the same time, they were not examined separately. The examined invasive species were based on the list of the 31 most aggressive terrestrial invasive plant species of Hungary, valid at the time of the survey. Data were collected only about the listed species:

Acer negundo, Amorpha fruticosa, Asclepia syriaca, Ailanthus altissima, Aster novi-belgii agg., Celtis occidentalis, Chencrus incertus, Echynocystis lobata, Elaeagnus angustifolia, Fallopia japonica, Fallopia sachalinensis, Fallopia × bohemica, Fraxinus pennsylvanica, Helianthus tuberosus, Heracleum mantegazzianum, Heracleum sosnowskyi, Hordeum jubatum, Humulus scandens, Impatiens glanduifera, Impatiens parviflora, Juncus tenuis, Prunus (Padus) serotina, Parthenocissus inserta, Parthenocissus quinquefolia, Phytolacca americana, Phytolacca esculenta, Robinia pseudoacacia, Rudbeckia laciniata, Solidago gigantea, Solidago canadensis, Vitis vulpina. Ambrosia artemisiifolia was left out of this survey due to its wide range distribution in the country.

The results were evaluated and the species' percentage group distribution groups were made according to Raunkiaer's life-forms, Borhidi's social behavior types, and the spatial distribution and density of each species.

Results

Altogether the following 19 invasive plant species were recorded on the entire length of the surveyed railway track section:

- *Acer negundo* L. – Boxelder maple
- *Amorpha fruticosa* L. – False indigo bush
- *Asclepias syriaca* L. – Common milkweed
- *Ailanthus altissima* (Mill.) Swingle – Tree of heaven
- *Aster novi belgii agg.* L. – New York aster species
- *Celtis occidentalis* L. – Hackberry
- *Cenchrus incertus* M.A. Curtis – Common sandbur
- *Elaeagnus angustifolia* L. Russian Olive
- *Fallopia × bohemica* (Chrtek et Chrtková) J.P. Bailey – Bohemian knotweed
- *Fraxinus pennsylvanica* Marshall Green ash
- *Helianthus tuberosus* L.s.l. – Jerusalem arthichoke
- *Juncus tenuis* Willd. – Slender rush
- *Padus serotina* (ehrh.) Borkh. – Black cherry
- *Parthenocissus inserta* (A. Kern.) Fritsch – Thicket creeper
- *Parthenocissus quinquefolia* (L.) Planch. – Virginia creeper
- *Robinia pseudoacacia* L. – Black locust
- *Solidago gigantea* Aiton – Giant goldenrod

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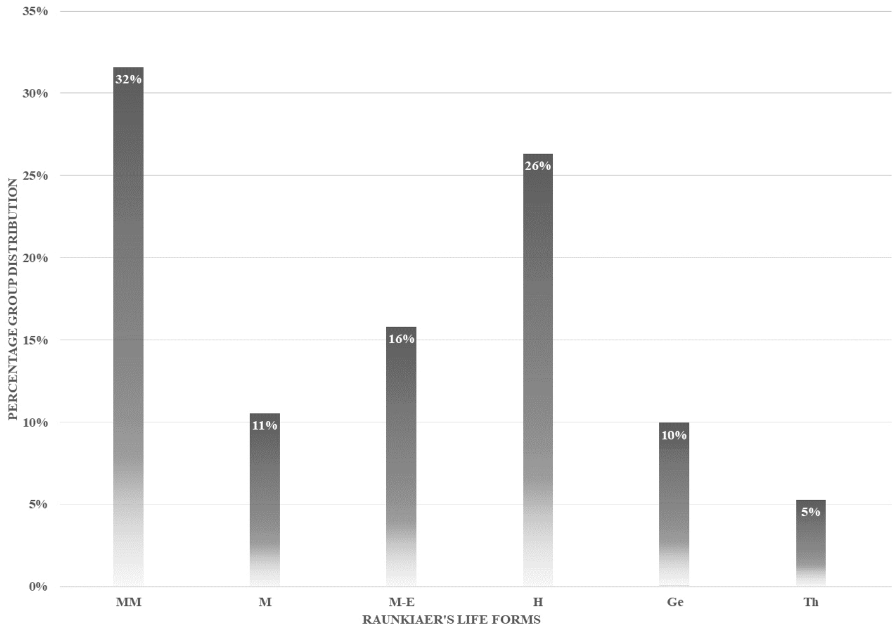

Figure 1. The Raunkiaer's life form types of the identified invasive species and their percentage group distribution

- *Solidago canadensis* L. – Canada gondenrod
- *Vitis vulpina* L. – Riverbank grape

Based on the percentage group distribution of the recorded species by Raunkiaer's life-form types, the species can be classified into 7 different life form categories (Fig. 1). Out of the categories mega-mesophanerophyta (woody plants) were present in the largest abundance, represented by 6 species (*Amorpha fruticosa, Ailanthus altissima, Celtis occidentalis, Fraxinus pennsylvanica, Padus serotina, Robinia pseudoacacia*). This group includes, but is not limited to, *Robinia pseudoacacia* and *Celtis occidentalis*, which are the most common species along the railway line. They followed by the hemicryptophyta species, which were represented by 5 taxa (*Asclepias syriaca, Aster novi belgii agg., Juncus tenuis, Solidago gigantea, Solidago canadensis*).

From the Borhidi social behavior types, 4 weed categories were represented by the species recorded (Fig. 2.), out of them the share of 'Alien competitors' (AC) was exceptionally high, with more than 50%. Alien competitors include, for example, *Acer negundo, Amorpha fruticosa* and *Asclepias syriaca*. The second most populous group was 'Introduced alien species' (I), represented 26% of the species (e.g. *Celtis occidentalis, Elaeagnus angustifolia* and *Fraxinus pennsylvanica*). Category „I" could mean the species once was cultivated, so therefore it means it was a conscious planting. Among the examples, *Celtis occidentalis* and *Fraxinus pennsylvanica* came to Hungary as park trees, while *Elaeagnus angustifolia* as raw materials for the wood industry. This could be an important factor when it comes to understanding the behavior of an invasive species.

The number of species present in the subsections (Fig. 3.) are unequal along the railway line. The map presents the difference between the settlements and the open track sections – those without constant trampling and other human activities, other than maintenance work. The species number is higher near the settlements, than the open track sec-

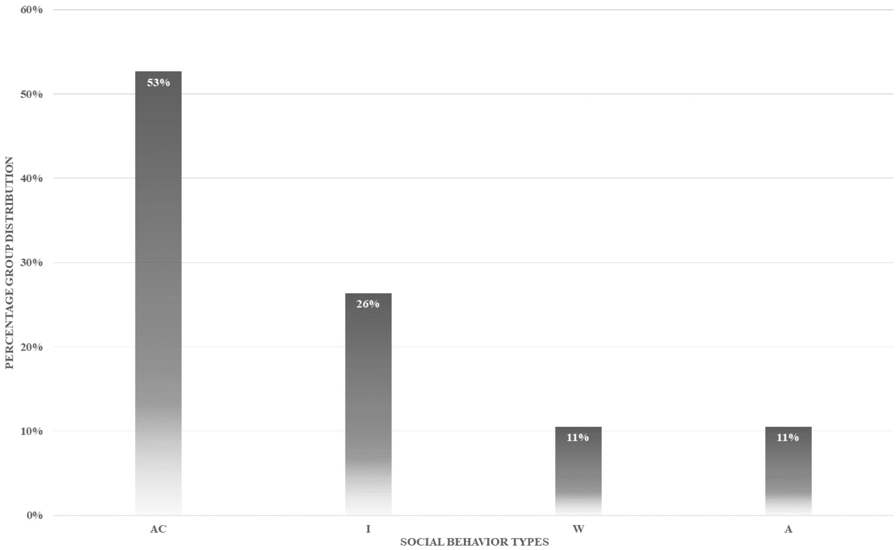

Figure 2. Group distribution of Borhidi Social Behavior Types of recorded taxa (A – Adventives, AC – Alien Competitors, I – Introduced alien species, W – Weeds)

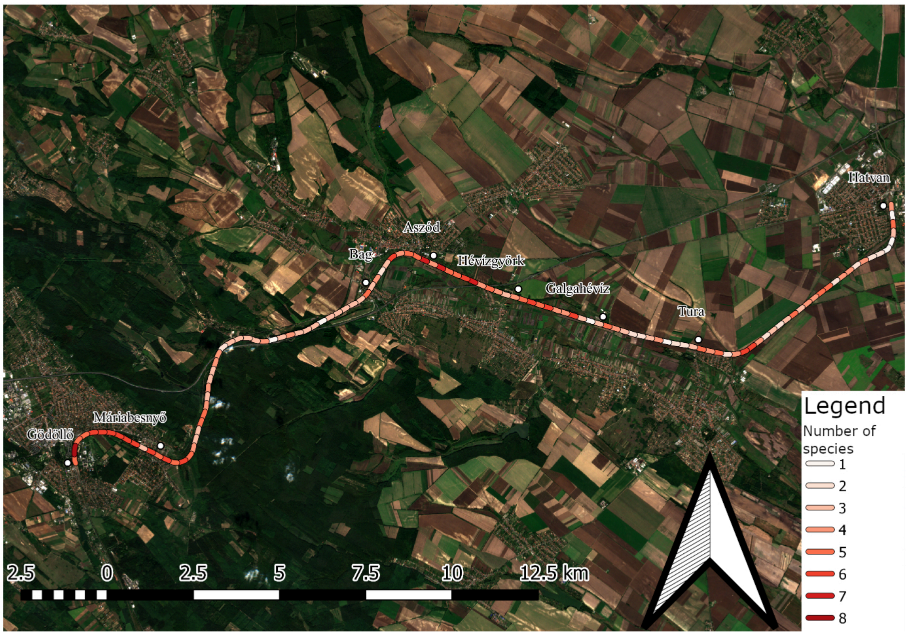

Figure 3. The number of species present in the subsections is indicated by a color scale. Between Gödöllő and Hatvan (October 2017). Source: ESA, Sentinel 2/A; QGIS 3.8.2, self-editing

tions. Certain species, such as *Juncus tenuis* and *Cenchrus incertus* are species specifically associated with stations, where there are poor quality, trampled and mowed grassy patches.

These facts indicate that the species composition is highly affected by the surrounding landscape. We highlight 3 species to investigate this phenomenon.

Figure 4 shows the presence of *Robinia*

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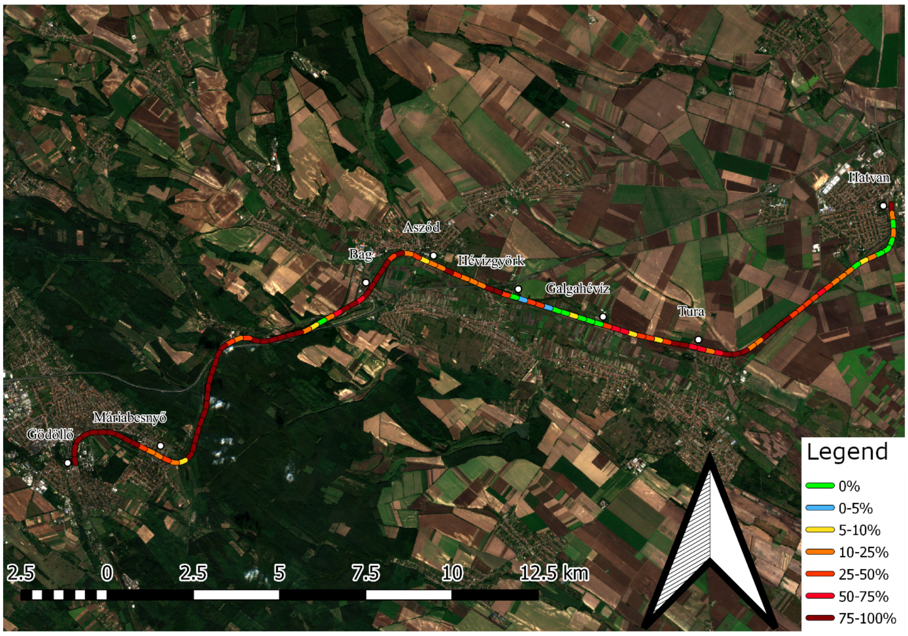

Figure 4. Black locust (*Robinia pseudoacacia*) infection on the surveyed road section between Gödöllő and Hatvan (October 2017). Source: ESA, Sentinel 2 / A; QGIS 3.8.2, self-editing

pseudoacacia on each small section. The most abundant invasive species of the survey, *Robinia pseudoacacia* was present at each recorded kilometer, and occurred in 108 out of the 120 subsections. *Robinia pseudoacacia* is a widespread invasive species throughout Hungary that causes many conservation problems (Kumschick et al., 2015).

Due to the abundance of *Robinia pseudoacacia*, we characterized those subsections where it did not occur or occurred with a small number of individuals.

i The first section was located between Domony-valley and Bag. This small section was almost completely free of invasive species. We found only a few *Solidago canadensis* individuals. It is a forested habitat patch dominated by *Acer* trees located between an agricultural area and the Bag train station, but its even more important feature is that it is much higher than the level of the rails, so the steep hillside and tree shade makes it difficult for invasive species to invade aggressively.

ii The second area is the small section in front of the Hévízgyörk railway station, where treatment is often done. Since the survey only examined the railway track up to 10 meters from the outer axis, the result does not mean that some seedlings or shoots could not appear here in a few years.

iii The third area is between the Hévízgyörk and Galgahévíz railway stations, which runs from halfway to the latter station. This section is covered rarely with trees, consists of 6 sub-sections, and only one of them has 2 specimens of Black locust. The surrounding areas are agricultural fields, so these populations are not stable, so this area is considered as one whole. There is agricultural activity on one side close to the rails, so regular eradication and the pressure of other species (including *Fraxinus pennsylvanica, Fraxinus excelsior* and some *Populus* trees) gives no opportunity for the species to settle.

iv The fourth area is the section next to the Hatvan marshalling yard. There are some stems from the 111th to the 118th small section, but due to regular eradication and agricultural activity, they are mainly seedlings.

Asclepias syriaca is one species that can be linked to linear infrastructure elements, such as roads or railways. Since this species prefers sandy soils and open, disturbed habitats, its presence near railway is expected.

Figure 5 shows that the species is present in the examined area, but not in great quantities. The most frequent subsections were placed between Máriabesnyő and Bag. The most dense subsections were present before and after Máriabesnyő station, where the vicinity of the inhibited area demands proper mowing, what creates good habitat for the species. Other sections were less frequently used by the species. The proximity of the railway is treated with herbicides, and the vegetation a little bit further is more and more closed, giving the species less opportunity to settle.

Figure 6 shows the presence of *Solidago canadensis* on the examined area. This species prefers more humid conditions. Between Gödöllő and Domonyvölgy it is more frequent. The area is well supplied with water by old drainage channels and the Besnyői-stream. After that there is two major occurence, one before Bag, near the Egres-stream; and the other near Hévízgyörk station, where there is an abandoned, wide, drainage channel under the railway embankment, which has been filled with dirt and occupied by weeds.

Discussion

Most of the found invasive species are not explicitly connected to the special habitats created by the railway structure, but they find their habitats in these areas as well. Stable populations run along railroads. These can be identified as borderline habitats, for these are in most cases line-like habitat patches neglected during maintenance work between railway areas and surrounding areas. Our results were not able to determine whether or not the found invasive plant species are explicitly connected to the habitats connected to the railway. In this regard, the species composition is more determined by the surrounding landscape than the railway structure for most species. Forman and McDonald (2007) and Mortensen et al. (2009) found that railway provide good habitat for invasive plant species for dispersal, as vehicles, wildlife and wind can move propagules alond roads which can increase the range of invasive species (Forman and McDonald 2007, Mortensen et al. 2009).

The 19 invasive species that were found along the railway lines were close to the 20 non-native species found in the survey carried out by Altay et al. (2015) in Turkey, where the three out of the found species (*Acer negundo, Ailanthus altissima, Robinia pseudoacacia*) are also registered as invasive in Hungary (Altay et al. (2015)).

Since lateral transect study wasn't performed, it cannot be said that more stable populations would be present along the railway line. The sudden appearance of large numbers of species may also indicate a larger population what has been cut in half by the railway. The examined railway line is well-bordered by trees in some areas, where most of the weedings take place only in the immediate vicinity of the railway tracks. In addition to plough fields, it is mainly *Robinia pseudoacacia* and *Asclepias syriaca* that line the railway embankments, as is often the case along other roads. Economic activities (timber planting, beekeeping) and poor quality treatments might encourage this phenomenon. During the study, the railway track section was not divided into right and left sides.

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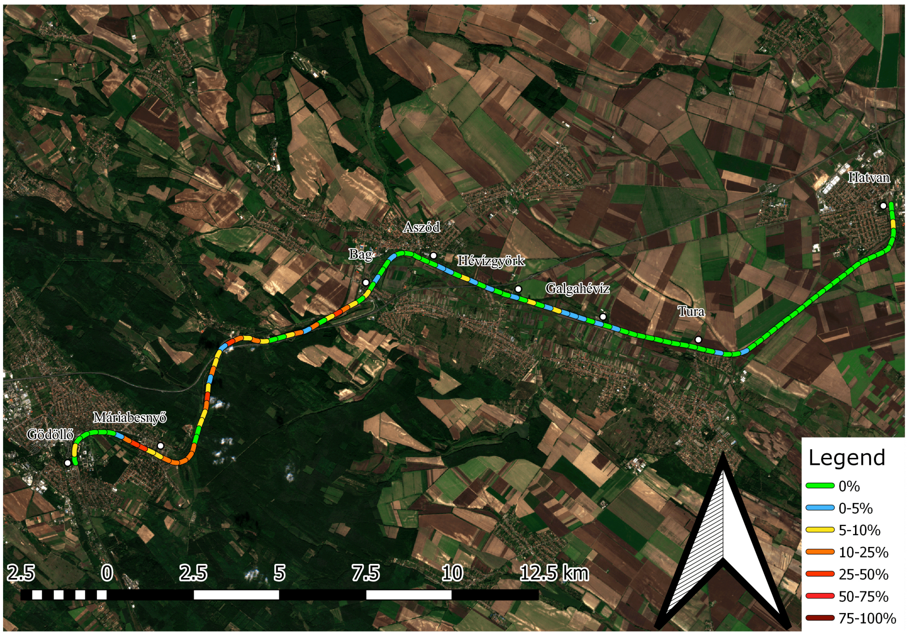

Figure 5. Common milkweed (*Asclepias syriaca*) infection on the surveyed road section between Gödöllő and Hatvan (October 2017). Source: ESA, Sentinel 2 / A; QGIS 3.8.2, self-editing

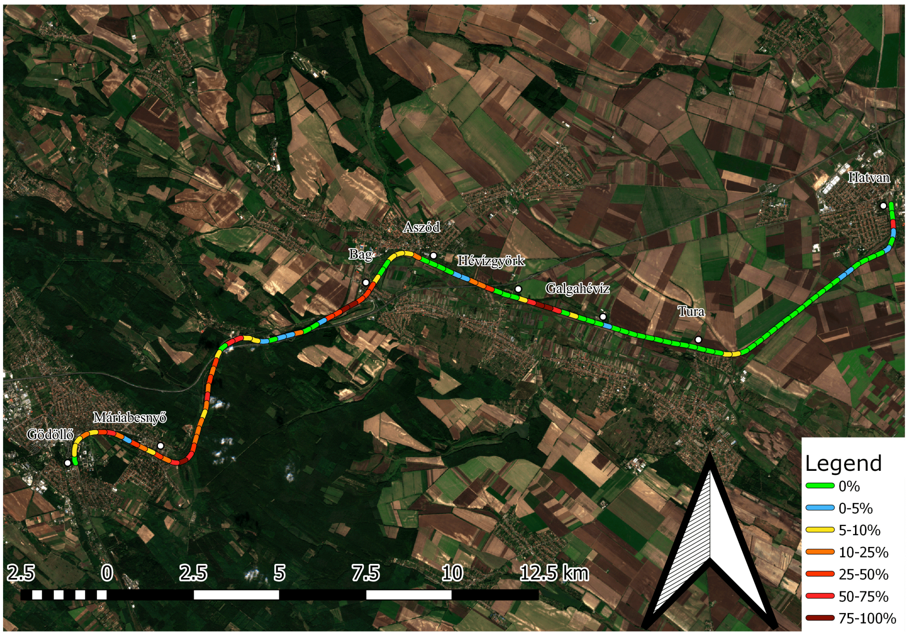

Figure 6. Canada goldenrod (*Solidago canadensis*) infection on the surveyed road section between Gödöllő and Hatvan (October 2017). Source: ESA, Sentinel 2 / A; QGIS 3.8.2, self-editing

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