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Full Length Research Paper

Invasive plant species in lawns of Belgrade roads

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In this paper the presence of invasive and potentially invasive plant species in lawns of roads in Belgrade, the capital city of the Republic of Serbia was analysed. The following lawn categories were selected for the purpose of analysis: the lawns of traffic roundabouts, the lane-dividing lawns, the lawns around roads and lawns around highway. Five-year research was conducted on 32 sites in Belgrade and 183 plant species were recorded. Out of that number, 18 plant species (9.84%) were characterised as invasive and potentially invasive. The presence of considerable number of invasive species within the researched lawn categories, despite the specific ambient condition, made the grassy spaces of the roads the potential centre of wider spread on the surrounding areas. Considering the fact that on the researched surfaces, cultivating and maintaining measures are occasionally applied, the number of invasive species was lower than that in the spaces not been maintained.

Key words: Invasive species, lawns, roads, invasion.

INTRODUCTION

Invasive species are increasingly becoming the focus of scientific attention, and the subject of many scientists research work. The widely accepted definition of invasive species is the one of the international organization IUCN, dating from 2003, and according to which invasive species are the ones that endanger the biodiversity of certain area, at the genetic, species and ecosystem level (Obratov-Petković et al., 2009). Another, equally complex definition is the one stating that the plant species originating from another floristic-geographic areas are considered invasive. These species in the competition process suppresses autochthonous genetic stock and distribute themselves across the remaining ecological niches (Federal Ministry of Environment and Tourism, 2008 to 2015). As a rule, these are the species of exceptional biological potential, of great competitive abilities, highly adaptable and aggressive (Vrbničanin et al., 2004).

Invasive plant species are a major problem and impediment to biodiversity conservation (Sala et al., 2000;McNeely et al., 2001; Cronk et al., 2001; Sukopp, 2002;Cox, 2004), causing considerable and irreversible environmental changes, primarily the changes in floristic structure and the succession process, and the socio-economic damage too. The first step of the invasive process is introduction, random or intentional. The degree and type of introduction is different in various species, however widespreading, regeneration and integration in previously uncontaminated habitat have been enabled by international trade roads and tourism development across relatively open borders. Climate changes, intensive agriculture, afforestation, trade in goods, passenger traffic, the increase in recreational fields and unplanned construction, cause the uncontrolled species widespread outside their native ranges (Kowarik, 2003). Invasive species first occupy unstable ecosystems (degraded and devastated spaces, arable land, and similar habitat), then spread to surrounding environment, causing homogenization of regional flora (Stevanović et al., 2009).

Cities and towns, in general, are commonly situated by major water flows and river flows which are important corridors of invasive species spreading (Obratov-Petković et al., 2009), thus making the areas along major or minor water flows the most endangered and the habitat of great number of neophyte. Another factor, considerably contributing to invasive species widespreading, is the anthropogenic factor.

Roads are required traffic infrastructural elements of both urban and rural area where the impact of anthro-

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pogenic factor is considerable. A part and frequently the only element of road grassy space is a lawn. Grassy space of traffic roundabouts represents the category of intensively cultivated lawn, primarily functioning as an element visible to active traffic participants (Stavretović, 2002). Spaces between road lanes are the untrodden on lawns of small dimensions and exposed to high levels of pollution. Grassy spaces around major roads and highways are somewhat extensively cultivated and maintained, due to the fact that they occupy larger space and that it is not demanded for them to be of high aesthetic value (Stavretović, 2002).

The main aim and purpose of this paper was to determine the presence of invasive species and potentially invasive plants within grassy spaces of different types of roads in Belgrade and to draw the conclusion on measures to be taken in order to reduce their presence. The conducted five-year floristic research enabled the defining of the lawn condition and the determination to what extent invasive species are present in order to keep record of their condition and tendencies in the future.

METHODOLOGY

Floristic research on road lawns on the territory of Belgrade, the capital of the Republic of Serbia, was conducted in the period of 1998 to 2002 and in year 2010. For the purpose of the research, the analysed road lawns were divided into four types of lawns: (i) grassy spaces of traffic roundabouts, (ii) the lane-dividing grassy spaces, (iii) grassy spaces around roads and (iv) lawns of major roads/ lawns of highway.

The research on invasive species presence in road lawns was conducted on 32 sites. Within the type of lawn of traffic roundabouts, four sites were researched, or more precisely, four most frequently used roundabouts in Belgrade. Lane-dividing lawns were researched on seven sites. Grassy spaces around roads were researched on 11 sites. Lawns of major roads (highway) included 10 sites on the highway section of Belgrade-Niš.

Within each road lawn type and on each site, the analysis of lawn structure and floristic composition was carried out according to Swiss-French phytocenological school method (Braun-Blanquet, 1964), regarding the fact that communities were not determined. In all the phytocenological recordings/screenings, a scale for number and covering was used (Braun-Blanquet, 1928) with the following numerical marks: + (rare species), 1, 2, 3, 4, and 5 (the highest mark shows the greatest domination of species in regard to both traits).

Plant identification was carried out according to the following reference sources: Josifović (1970 to 1977), Sarić (1986), Tutin et al. (1964 to 1980), Javorka et al. (1934), Kojić (1990), Šarić (1991) and Stavetović (2008). For the purpose of determining the presence of invasive species, data on species naturalisation in Central Europe, from three relevant “on line” data bases, were used: DAISIE European Invasive Alien Species Gateway (www.europe- aliens.org), covering 63 countries/regions, including islands and 39 marine and coastal areas, “CPS SKEW Schwarze Liste und Watch-Liste Invasive gebietsfremde Pflanzen” (www.cps-skew.ch) and Global Invasive Species Database (www.issg.org/database). In order to determine a species as invasive, the survey of its status in the base was conducted in regard to the countries in the region; Hungary, Romania, Bulgaria and Croatia. If the species was characterized as invasive (mark alien/established) in just one of these countries, the status of invasive species, even in the area of research, was given to it. The lists of authors were used too: Vrbničanin et al. (2004), Boršić et al. (2008) and Kaufman et al. (2007).

Based on the research results, the conclusions were made on the presence of invasive and potentially invasive species, the most represented plant families within types of grassy spaces of roads, as well as on their presence in the whole area of the research.The percent of invasive species representation and the ratio between invasive and other species was determined. It was also confirmed, which of the researched types of road grassy spaces could be characterised as one with the highest presence of invasive species.

RESULTS

Lawns of traffic roundabouts (I)

In major and more complex junctions, roundabouts are set up. The important element of roundabout space is greenery. For the purpose of visibility in traffic, low elements of greenery, soil covers and lawns are used in these spaces. Lawns of these spaces must regularly be mowed and appropriatelly maintained. Aesthetics is their main purpose, and grass should in no way be an impediment to the traffic. Plants in these spaces should be resistant to polluting substances (P, CO, CO_2, soot, salt).

Floristic composition and structure of lawns of roundabouts greenery was researched on four most frequently used sites in Belgrade. In roundabout lawns, 58 plants were noticed (Table 1). Lawn height in these spaces ranged from 3 to 16 cm, with average height of 8 cm. Regular mowing of these spaces is carried out for the purpose of traffic safety. Conducting the above stated measures caused the high level of lawn canopy cover which amounted to 85 to 95%.

Out of the total number of recorded plants, six (10.34%) (Figure 1) were characterised as invasive and potentially invasive species: *Eleusine indica*, *Sorghum halepense*, *Veronica persica*, *Polygonum aviculare*, *Artemisia vulgaris* and *Cynodon dactylon*. *C. dactylon* species was distinguished by the highest values of the measured parameters (number and cover) and was noticed on all four sites, with marks 2.2, 1.2, 1.1 and +. These are high values considering the fact that four existing good-quality grass species (*Poa pratensis*, *Lolium perenne*, *Festuca rubra* and *Poa trivialis*) had marks 1.2 and +. Invasive species *Polygonum aviculare* and *Veronica persica* were recorded on two sites with marks +, whereas others were represented on one site, with mark + too.

Lane- dividing lawns (II)

Lane-dividing spaces differ from traffic roundabouts. The maintaining of these spaces is not conditioned by visual obstacles, because it is not necessary for drivers to have

Table 1. Lawns of traffic roundabouts. Cordinates of sampling site: (1) 44°48'54.60" N latitude, 20°29'30.04"E longitude. (2) 44°48'8.90" N latitude, 20°27'58.83" E longitude.(3) 44°49'27.46" N latitude, 20°24'48.31" E longitude.(4) 44°47'15.37" N latitude, 20°27'57.16" E longitude.

Size area (m^2)		**200**	**200**	**200**	**200**
Lawn height (cm)		**16**	**5**	**8**	**3**
Total cover (%)		**85**	**95**	**90**	**85**
Inclination		**2**	**2**	**2**	**2**
Exposition		**/**	**/**	**/**	**/**
Number of recorded plant		**24**	**27**	**33**	**16**
Number of sampling site		**1**	**2**	**3**	**4**
S/N	**Species**				
1	*Lolium perenne*	1.2	1.2	1.2	1.2
2	*Poa pratensis*	1.2	1.2	+	1.2
3	*Festuca rubra*	R			+
4	*Poa trivialis*	+			
5	*Cynodon dactylon*	+	2.2	1.1	1.2
6	*Hordeum murinum*	1.2		1.2	1.2
7	*Poa annua*	1.2	+		2.2
8	*Agropyrum repens*	+	R	+	
9	*Poa bulbosa*	+	R		+
10	*Bromus mollis*	R	R	+	
11	*Dactylis glomerata*	R	R	R	
12	*Setaria glauca*			1.2	
13	*Arrhenatherum elatius*	+			
14	*Elesusine indica*				+
15	*Sorghum halepense*			+	
16	*Bromus sterilis*	R			
17	*Digitaria ciliaris*				R
18	*Medicago sativa*	R		R	
19	*Trifolium repens*		1.1		+
20	*Medicago lupulina*			+	+
21	*Lotus corniculatus*			R	
22	*Trifolium patens*			R	
23	*Vicia cracca*			R	
24	*Bellis perennis*	+	3.1	2.1	+
25	*Taraxacum officinale*	1.1	R	R	+
26	*Achillea millefolium*	+	+	1.1	+
27	*Convolvulus arvensis*	R	+	R	+
28	*Erodium cicutarium*	2.1	R	1.1	1.1
29	*Plantago lanceolata*	1.1		2.1	R
30	*Veronica persica*	+		+	
31	*Polygonum aviculare*		+	+	
32	*Oxalis acetosella*		+		
33	*Potentilla reptans*		+		
34	*Capsella bursa pastoris*	+			
35	*Lepidium draba*	+			
36	*Plantago media*		R		
37	*Solanum nigrum*		R		
38	*Leontodon autumnalis*		R		
39	*Hypochoeris radicata*		R		
40	*Stellaria media*			R	
41	*Senecio vulgaris*		R		

Table 1. Contd.

42	*Daucus carota*			R
43	*Prunella vulgaris*		R	
44	*Polygonum convolvulus*			R
45	*Crepis foetida ssp.rhoeadifolia*			R
46	*Diplotaxis tenifolia*			R
47	*Lamium purpureum*	R		
48	*Hieracium pilosella*		R	
49	*Rumex crispus*			R
50	*Cirsium arvense*			R
51	*Anagallis arvensis*			R
52	*Artemisia vulgaris*			R
53	*Geranium molle*			
54	*Leontodon hispidus*		R	
55	*Veronica chamaedrys*		R	
56	*Sonchus arvensis*		R	
57	*Silene vulgaris*			R
58	*Rorippa sylvestris*			R

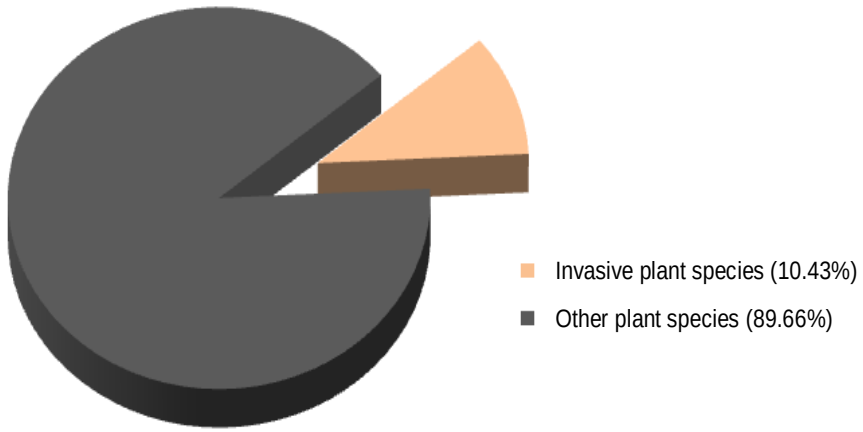

Figure 1. The representation of invasive species in lawns of traffic roundabouts.

clear visibility of opposite lane, unless in proximity to junctions or turnings. Plant species in these space must be resistant to polluting substances, salt and compressed soil. Plants height, the way of growth and coloration are not of particular importance to lawns of this type of traffic road greenery.

Floristic composition and lane-dividing lawns structure was researched on seven sites in Belgrade. In the grassy spaces, the presence of 78 plant species was observed (Table 2). The average height of the analysed lawns of this type was 23 cm, with the average lawn canopy cover of 63.57%.

Out of the total number of recorded plants, 5 (6.41%) (Figure 2) were characterised as invasive and potentially invasive species: *Stenactis dactylon, Polygonum aviculare, Veronica persica, Stenactis annua* and *Sonchus oleraceus*. *Cynodon dactylon* species was distinguished by the highest values of the measured parameters (number and cover) and was recorded on three sites, with marks 1.2, 1.2 and +. Species *Polygonum aviculare*, *Veronica persica* and *Stenactis annua* were recorded on two sites with values of the measured parameters as 2.1, 1.1, that is, +, whereas other invasive species were represented on one site with mark +.

Lawns around roads (III)

Lawns around roads are an important element in connecting of green spaces across regions. Besides its aesthetic and sanitary function, very important functions

Table 2. Lane-dividing lawns. Coordinates of sampling site: (1) 44°49'21.57" N latitude, 20°29'26.71" E longitude; (2) 44°47'26.87" N latitude, 20°25'26.03" E longitude; (3) 44°49'20.11" N latitude, 20°24'29.03" E longitude; (4) 44°49'9.65" N latitude, 20°24'18.48" E longitude; (5) 44°46'5.06" N latitude, 20°24'42.44" E longitude; (6) 44°49'20.34" N latitude, 20°23'55.15" E longitude; (7) 44°44'23.74« N latitude, 20°25'11.67« E longitude.

Size area (m^2)		**500**	**500**	**85**	**10**	**150**	**10**	**30**
Lawn height (cm)		**20**	**11**	**50**	**20**	**22**	**20**	**18**
Total cover (%)		**85**	**75**	**50**	**50**	**50**	**40**	**95**
Inclination		**/**	**/**	**/**	**/**	**/**	**/**	**25**
Exposition		**/**	**/**	**/**	**/**	**/**	**/**	**W**
Number of recorded plant		**39**	**20**	**11**	**6**	**30**	**3**	**32**
Number of sampling site		**1**	**2**	**3**	**4**	**5**	**6**	**7**
S/N	**Species**							
1	*Lolium perenne*	1.1	+	1.2	1.2	+		+
2	*Festuca rubra*	2.2	R			+		
3	*Poa pratensis*		R			+		1.2
4	*Poa trivialis*	+						
5	*Festuca pratensis*		R					
6	*Agropyrum repens*	+	+	1.2		R		1.2
7	*Dactylis glomerata*	R		R		R		R
8	*Hordeum murinum*		2.2			2.2		1.2
9	*Bromus sterilis*	+			+			1.2
10	*Cynodon dactylon*	+	1.2			1.2		
11	*Sclerohloa dura*		+		1.2	R		
12	*Avena fatua*				2.2		2.2	
13	*Bromus sterilis*		+			+		
14	*Poa annua*		R	R				
15	*Hordeum murinum ssp. Leporinum*					+		
16	*Poa bulbosa vivipara*							+
17	*Setaria viridis*					R		
18	*Setaris glauca*			R				
19	*Digitaria sanguinalis*			R				
20	*Arrhenatherum elatius*	R						
21	*Lolium italicum*					R		
22	*Holcus lanatus*					R		
23	*Poa bulbosa*		R					
24	*Medicago sativa*	+				1.1		+
25	*Vicia cracca*	2.1						
26	*Lotus corniculatus*	R						R
27	*Medicago falcata*					R		
28	*Vicia sativa*							R
29	*Trifolium repens*			R				R
30	*Trifolium pratense*	R						
31	*Plantago lanceolata*	+	3.1	2.1	1.1	1.1		2.1
32	*Erodium cicutarium*		R	+	+	+		2.1
33	*Convolvulus arvensis*	+	R	1.1		+		R
34	*Taraxacum officinale*	+	+	+				R
35	*Capsella bursa pastoris*	1.1				+		1.1
36	*Bellis perennis*	+	R			+		
37	*Cirsium acaule*	R				R		R
38	*Polygonum aviculare*		+				2.1	
39	*Veronica persica*	1.1	+					
40	*Cichorium intybus*	R	1.1					

Table 2. Contd.

41	*Lepidium draba*	1.1							R
42	*Chenophodium murale*		+					+	
43	*Lamium purpureum*	R							R
44	*Cirsium lanceolatum*	R					R		
45	*Stenactis annua*						+		+
46	*Leontodon hispidus*	R							R
47	*Stellaria media*	+							
48	*Chenopodium album*	+							
49	*Rorippa sylvestris*	+							
50	*Consolida regalis*	+							
51	*Polygonum convolvulus*						+		
52	*Geranium molle*	+							
53	*Ranunculus acris*								+
54	*Geranium dissectum*								+
55	*Achillea millefolium*						R		
56	*Arenaria serpyllifolia*						R		
57	*Matricaria chamomilla*	R							
58	*Hypochoeris radicata*	R							
59	*Verbascum phlomoides*	R							
60	*Veronica serpyllifolia*	R							
61	*Anchusa officinalis*	R							
62	*Sonchus oleraceus*	+							
63	*Daucus carota*						R		
64	*Chenopodium murale*						R		
65	*Calystegia sepium*						R		
66	*Lactuca serriola*						R		
67	*Verbena officinalis*								R
68	*Malva sylvestris*	R							
69	*Sinapis arvensis*	R							
70	*Geum urbanum*	R							
71	*Euphorbia cyparissias*								R
72	*Fumaria officinalis*								R
73	*Cicorium intibus*								R
74	*Plantago major*								R
75	*Silene vulgaris*								R
76	*Tragopogon pratensis*								R
77	*Rumex crispus*								R
78	*Hieracium pilosella*								

of these lawns are anti-erosive and ameliorative functions. Aesthetic importance and the role of physical barrier between active and passive participants in traffic, distinguish these surfaces as highly necessary and important in human environment. These grassy spaces are highly endangered by polluters, heavy metals, sooth, salt, waste and motor vehicles.

Floristic composition and structure of lawns around roads were surveyed on 11 sites in Belgrade. In this type of lawn, the presence of 91 plant species was stated (Table 3). The height of this lawn type was 29.45 cm, which means that it was considerably greater than that in previous types. The lawn canopy cover decreased in almost equal proportion to its height, which amounted to 60.90% in the analysed spaces.

Out of the total number of the recorded plants, 10 (10.98%) (Figure 3) were characterised as invasive and potentially invasive species: *Cynodon dactylon*, *Ambrosia artemisiifolia*, *Stenactis annua*, *Polygonum aviculare*, *Aster lanceolatum*, *Artemisia vulgaris*, *Veronica persica, Bromus tectorum* and germs of dendrous species *Robinia pseudoacacia* and *Acer negundo. Cynodon dactylon* species was distinguished by the highest values of the measured parameters (number and cover) and was

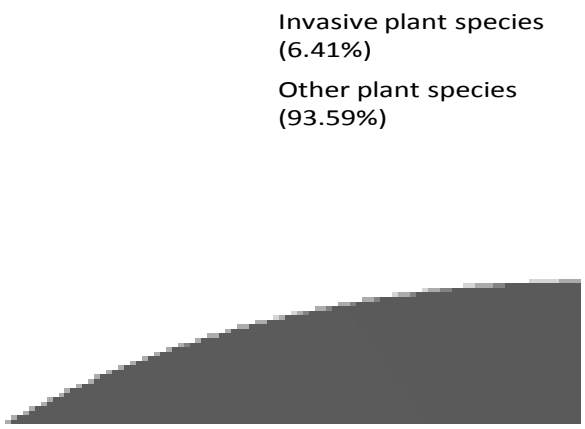

Figure 2. The representation of invasive species in lane-dividing lawns.

recorded on five sites, with marks 1.2, that is, +.

Species *Ambrosia artemisiifolia* is recorded on 2 sites, with marks 1.1. Species *Stenactis annua*, *Polygonum aviculare*, *Robinia pseudoacacia* and *Acer negundo* are recorded on 2 sites with mark +, whereas other species are present on 1 site, with the same mark.

Besides the presence of invasive species, this type of lawn was characterized by high level of weed species presence. However, seven good-quality grass species were also present (*Lolium perenne, Poa pratensis, Festuca rubra, Festuca ovina, Poa trivialis* and *Festuca pratensis*), which was considerably more in comparison to the previously described types of grassy spaces of roads. This could be explained by the fact that heterogeneous traits of the environment micro-conditions caused the diversity of the plant species.

Lawns around highways (IV)

The most important function of lawns around major roads is protection against erosion, but they also have important aesthetic purpose. This type of lawn differs from other types of road lawns in its size, that is, width around road and length along the road. Road length demands change in ambient, in the sense of coloration and texture change and in avoiding of much uniformity of ambient. All this that has been stated, makes this type of greenery characteristic and specific by its needs and ways of establishment and maintenance.

Floristic composition and this lawn type structure were researched on highway Belgrade - Niš (E75) on the section in Belgrade, which connects to the city centre. Grassy spaces of this type were researched on 10 sites. In grassy spaces around highway, 135 plant species were observed (Table 4). The number of plants record on each site ranged from 24 to 55. It was evident that the greatest number of species was observed in road lawns within this type, in total and in each site. The average height of these lawns was 21.7 cm, with average grass canopy cover of 69.5%.

Out of the total, the number of recorded plants was 13 (9.63%) (Figure 4) and were characterised as invasive and potentially invasive species: *Cynodon dactylon*, *Stenactis annua*, *Sonchus oleraceus*, *Veronica persica*, *Polygonum aviculare*, *Amaranthus retroflexus*, *Oxalis stricta, Bidens frondosa*, *Artemisia vulgaris*, *Fragaria indica*, *Bromus tectorum, Rubus caesius* and *Acer negundo. Cynodon dactylon* species was distinguished by the highest values of the measured parameters (number and cover) and was recorded on seven sites, with marks 1.2, that is, +. Species *Stenactis annua* and *Sonchus oleraceus* were recorded on four sites, with mark +. Species *Veronica persica* and *Polygonum aviculare* were recorded on three sites, with mark +. Other species were present on one of the lawns for which the possibility of applying extensive cultivation and maintenance measures are of importance, that is the minimum financial investment, which accounts for the presence of the greatest number of invasive species. In these grassy spaces, invasive species *Cynodon dactylon* showed high resistance to the conditions.

Table 3. Lawns around roads. Cordinates of sampling site: 1) 44°47'19.42« N latitude, 20°25'14.47« E longitude; 2) 44°46'54.36« N latitude, 20°24'35.50« E longitude; 3) 44°48'33.39« N latitude, 20°30'3.74« E longitude; 4) 44°46'24.78« N latitude, 20°24'29.08« E longitude; 5) 44°47'39.49« N latitude, 20°26'33.49« E longitude; 6) 44°47'30.73« N latitude, 20°26'29.24« E longitude; 7) 44°47'20.61« N latitude, 20°26'27.37« E longitude; 8) 44°47'10.85« N latitude, 20°26'23.39« E longitude; 9) 44°49'26.46« N latitude, 20°24'16.95« E longitude; 10) 44°44'36« N latitude, 20°25'15.95« E longitude; 11) 44°44'33.03« N latitude, 20°25'0.09« E longitude.

Size area (m^2)		**100**	**600**	**20**	**20**	**50**	**100**	**90**	**100**	**35**	**100**	**100**
Lawn height (cm)		**17**	**25**	**80**	**70**	**6**	**15**	**9**	**7**	**40**	**25**	**30**
Total cover (%)		**70**	**70**	**50**	**50**	**100**	**70**	**40**	**60**	**60**	**95**	**95**
Inclination		**/**	**35**	**10**	**/**	**35**	**20**	**5**	**5**	**/**	**/**	**/**
Exposition		**/**	**E**	**NW**	**/**	**W**	**/**	**S**	**N**	**/**	**/**	**/**
Number of recorded plant		**21**	**36**	**21**	**18**	**12**	**8**	**8**	**5**	**11**	**27**	**24**
Number of sampling site		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
S/N	**Species**											
1	*Lolium perenne*	+	R	+			2.2				2.2	
2	*Poa pratensis*	R		+			2.2				3.2	+
3	*Festuca rubra*			+				1.2	2.2			
5	*Festuca ovina*							+	1.2			
6	*Poa trivialis*		R		1.2							
7	*Poa annua*	R										
8	*Festuca pratensis*				R							
9	*Hordeum murinum*	3.2	1.2	2.2	1.2			1.2		2.2	1.2	2.2
10	*Agropyrum repens*	+	+	1.2	+			R			R	
11	*Cynodon dactylon*	+	1.2	1.2	+					+		
12	*Bromus mollis*	1.2	1.2	+						+		1.2
13	*Bromus sterilis*		+								1.2	1.2
14	*Poa bulbosa vivipara*										+	1.2
15	*Sclerochloa dura*	R	R									
16	*Dactylis glomerata*										R	R
17	*Vulpia myuros*		3.2									
18	*Poa bulbosa*								2.2			
19	*Poa annua*		+									
20	*Setaria viridis*			+								
21	*Avena fatua*			R								
22	*Bromus tectorum*		+									
23	*Aegilops cylindrica*		R									
24	*Holcus lanatus*			R								
25	*Bachypodium sylvaticum*						R					
26	*Medicago sativa*	R	R							2.1	+	2.1
27	*Trifolium repens*							1.1			+	+
28	*Trifolium pratense*							+			+	R
29	*Lotus corniculatus*					R					R	R
30	*Medicago lupulina*		R							+		
31	*Medicago falcata*		R						R			
32	*Vicia sativa*										R	R
33	*Trifolium hibridum*										R	R
34	*Melilotus officinalis*					+						
35	*Trifolium patens*		R									
36	*Medicago arabica*		R									
37	*Trifolium campestre*		R									
38	*Plantago lanceolata*	1.1	+	1.1						R	2.1	2.1
39	*Erodium cicutarium*		+	+						R	+	R
40	*Convolvulus arvensis*	+		R	1.1						R	R

Table 3. Contd.

41	*Malva sylvestris*	R	R		+				1.1		
42	*Achilea millefolium*		R	R						+	R
43	*Stellaria media*								1.1	R	R
44	*Capsella bursa pastoris*	+								+	R
45	*Lepidium draba*	+								R	R
46	*Taraxacum officinale*	+			R					R	
47	*Daucus carota*		R	R					R		
48	*Ambrosia artemisiifolia*	1.1			1.1						
49	*Stenactis annua*		+	+							
50	*Sonchus arvensis*		R		+						
51	*Matricaria chamomilla*	R	R								
52	*Chenopodium album*	R		R							
53	*Polygonum aviculare*	+				+					
54	*Alchemilla vulgaris*		R			R					
55	*Crepis biennis*		R			R					
56	*Leontodon hispidus*									R	R
57	*Cyrsium arvense*									R	R
58	*Thymus marschallianus*									R	R
59	*Rumex crispus*				R						R
60	*Plantago major*	R								R	
61	*Bellis perennis*			+							
62	*Centaurea jacea*				+						
63	*Polygonum convolvulus*			+							
64	*Althaea officinalis*				R						
65	*Cirsium acaule*			R							
66	*Senecio vulgaris*	R									
67	*Stellaria holostea*		R								
68	*Fumaria officinalis*		R								
69	*Cichorium intybus*		R								
70	*Cerastium brachypetalum*		R								
71	*Aster lanceolatum*		+								
72	*Lactuca serriola*					R					
73	*Verbascum phlomoides*		R								
74	*Lamium amplexicaule*				R						
75	*Geranium molle*								R		
76	*Artemisia vulgaris*				+						
77	*Calystegia sepium*			R							
78	*Alyssum desertorum*		R								
79	*Veronica persica*									+	
80	*Cicorium intibus*									R	
81	*Papaver rhoeas*		R								
82	*Hedera helix*					5.3	1.3				
83	*Clematis vitalba*				+						
84	*Sambucus nigra*					R	+	1.1			
85	*Tillia argentea*					+			+		
86	*Robinia pseudoacacia*					+	+				
87	*Aesculus hypocastanum*					R		R			
88	*Ulmus efusa*						R				
89	*Cornus mas*						R				
90	*Acer negundo*				+	+					
91	*Budleja davidii*				R						

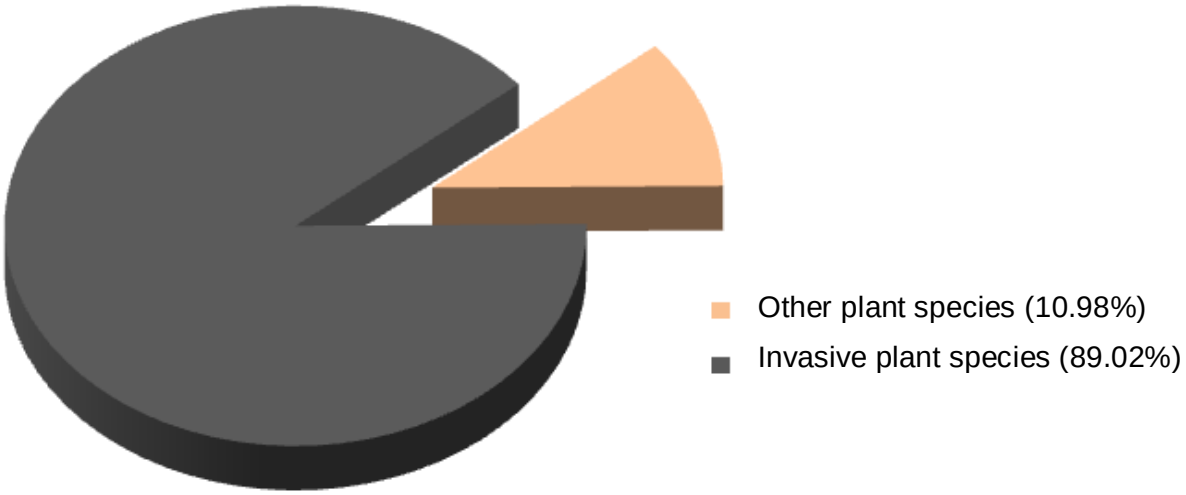

Figure 3. The representation of invasive species in lawns around roads.

Table 4. Lawns around highways E-75 section Mostarska petlja. Coordinates of sampling site: 1) 44° 47' 49.19" N latitude, 20° 27' 4.26" E longitude; 2) 44° 47' 47.65" N latitude, 20° 27' 13.49" E longitude; 3) 44° 47' 43.52" N latitude, 20° 27' 24.25" E longitude; 4) 44° 49' 6.64" N latitude, 20° 24' 26.55" E longitude; 5) 44° 48' 26.51" N latitude, 20° 25' 59.82" E longitude; 6) 44° 48' 34.82" N latitude, 20° 25' 32.98" E longitude; 7) 44° 48' 29.96" N latitude, 20° 25' 46.62" E longitude; 8) 44° 48' 20.30" N latitude, 20° 25' 55.76" E longitude; 9) 44° 48' 27.01" N latitude, 20° 25' 49.14" E longitude; 10) 44° 48' 55.87" N latitude, 20° 24' 50.36" E longitude.

Size area (m^2)		**400**	**100**	**50**	**50**	**250**	**250**	**600**	**125**	**150**	**160**
Lawn height (cm)		**45**	**30**	**22**	**15**	**20**	**15**	**7**	**18**	**15**	**30**
Total cover (%)		**70**	**80**	**60**	**40**	**50**	**90**	**70**	**95**	**80**	**60**
Inclination		**40**	**3**	**35**	**40**	**30**	**/**	**70**	**1**	**20**	**30**
Exposition		**NE**	**NE**	**E**	**S**	**S**	**/**	**NW**	**S**	**S**	**NW**
Number of recorded plant		**55**	**41**	**25**	**31**	**26**	**38**	**24**	**30**	**36**	**33**
Number of sampling site		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
S/N	**Species**										
1	*Poa pratensis*	+	1.2	R		R	+	2.2	+	1.2	
2	*Lolium perenne*	R			R		+	1.2	+	1.2	1.2
3	*Festuca rubra*				R		1.2	1.1	1.2	1.2	1.2
4	*Festuca arundinacea*		+	1.2							
5	*Festuca ovina*	R					+				
6	*Agrostis alba*			R							R
7	*Poa trivialis*							1.2			
8	*Agrostis vulgaris*	+									
9	*Festuca pratensis*										+
10	*Bromus mollis*	+	1.2	2.2	R	1.2	R	+	1.2	+	R
11	*Dactylis glomerata*		+	R	R	R	R	+	R	R	R
12	*Agropyrum repens*	R		R		R	R		3.2	2.2	R
13	*Cynodon dactylon*	+	+		+		+		1.2	1.2	+
14	*Hordeum murinum*	2.2	+		R		R	+	1.2		
15	*Bromus sterilis*	+		1.2	R				+	+	
16	*Holcus lanatus*		R	R				+	+	R	
17	*Poa bulbosa*	+	R		1.2	R					
18	*Poa bulbosa vivipara*	+		+	R	+					
19	*Vulpia ciliata*	2.2	2.2			1.2					
20	*Aegilops cylindrica*								+	+	

Table 4. Contd.

21	*Digitaria sanguinalis*				R	R			+		
22	*Poa annua*								+	+	
23	*Lolium multiflorum*				+	R					
24	*Alopecurus pratensis*	+									
25	*Sclerochloa dura*								+		
26	*Triticum turgidum*				R						
27	*Bromus tectorum*	R									
28	*Arrhenatherum elatius*	R									
29	*Avena fatua*										R
30	*Arrhenatherum elatius*							R			
31	*Medicago sativa*	+	R	R	R	R			+	R	
32	*Medicago lupulina*	1.1	2.1				+				R
33	*Medicago falcata*				+	+	R				
34	*Lotus corniculatus*		R	R			R	R		+	R
35	*Trifolium pratense*		R	R					+	+	
36	*Medicago minima*	+	+			R					
37	*Vicia cracca*	+					+			R	
38	*Trifolium repens*								+	+	
39	*Vicia sativa*	+	R								
40	*Trifolium incarnatum*			R						R	
41	*Trifolium arvense*		R	R							
42	*Trifolium hybridum*			R							
43	*Trifolium campestre*		R								
44	*Astragalus cicer*		R								
45	*Plantago lanceolata*	1.1	1.1	2.1	R	+	+	1.1		1.1	1.1
46	*Erodium cicutarium*	R	+	R	2.1	2.1	R		R	R	R
47	*Achillea millefolium*	+	R	+	R		+	R	2.1	2.1	R
48	*Convolvulus arvensis*	R	R	R				+	+	+	+
49	*Bellis perennis*		R	R		R	R			+	1.1
50	*Sinapis arvensis*	R	R		R	R					R
51	*Ranunculus sardous*	R	R		R	R					R
52	*Taraxacum officinale*						R	1.1		R	1.1
53	*Prunella vulgaris*							+	+	+	R
54	*Potentilla reptans*	+							+	R	R
55	*Verbascum phlomoides*	R		R				R	+		
56	*Stenactis annua*				+			+	+	+	
57	*Cirsium lanceolatum*		R	R				R		R	
58	*Sonchus oleraceus*			+	+		+				+
59	*Senecio vulgaris*	R	R				R				R
60	*Silene vulgaris*		R					R	R	R	
61	*Rumex obtusifolius*						R		R	R	R
62	*Euphorbia helioscopia*		+			+	R				
63	*Sonchus asper*				R	R	R				
64	*Arenaria serpyllifolia*	R	R		R						
65	*Leontodon hispidus*	R		R				R			
66	*Stellaria holostea*	R	R		R						
67	*Lepidium draba*	R	R						R		
68	*Veronica persica*		+		+	+					
69	*Cerastium brachypetalum*				2.1		R				
70	*Gallium aparine*							+			1.1
71	*Papaver rhoeas*	+					+				

Table 4. Contd.

72	*Geranium molle*	+	R								
73	*Geranium robertianum*							R		+	
74	*Plantago major*							R		R	
75	*Daucus carota*	R					R				
76	*Matricaria chamomilla*				R						R
77	*Triticum aestivum*	R			R						
78	*Veronica serpyllifolia*		R		R						
79	*Sonchus arvensis*			R	R						
80	*Alyssum alyssoides*	R			R						
81	*Senecio vernalis*				R	R					
82	*Lactuca serriola*	R					R				
83	*Diplotaxys tenuifolia*		R				R				
84	*Plantago media*			R					R		
85	*Polygonum aviculare*	+	+							+	
86	*Scherardia arvensis*					+					
87	*Amaranthus retroflexus*										+
88	*Ranunculus arvensis*								+		
89	*Thymus marschallianus*						+				
90	*Galium molugo*							+			
91	*Tragopogon dubius*	R									
92	*Thymus serpyllum*										R
93	*Polygonum convolvulus*		R								
94	*Rumex crispus*									R	
95	*Oxalis stricta*						+				
96	*Scherardia arvensis*								R		
97	*Bidens frondosa*									+	
98	*Cichorium intybus*										R
99	*Pimpinella saxifraga*						R				
100	*Aster novi-belgii*										R
101	*Bilderdykia convolvulus*	R									
102	*Alium sativum*	R									
103	*Artemisia vulgaris*	+									
104	*Calepina iregularis*		R								
105	*Carex nitida* Host.						R				
106	*Viola tricolor*										R
107	*Capsella bursa pastoris*								R		
108	*Chenophodium opulifolium*				R						
109	*Malva sylvestris*									R	
110	*Salvia pratensis*						R				
111	*Galium verum*						R				
112	*Euphoprbia cyparissias*		R								
113	*Lamium maculatum*									R	
114	*Lapsana communis*	R									
115	*Crepis foetida ssp.rhoeadifolia*					R					
116	*Allium vineale*	R									
117	*Alchemilla vulgaris*	R									
118	*Carduus acanthoides*	R									
119	*Fragaria indica*						+				
120	*Chondrilla juncea*		R								
121	*Knautia arvensis*						R				
122	*Ranunculus polyanthemos*						R				
123	*Rorippa sylvestris*										R

Table 4. Contd.

124	*Chenophodium polyspermum*				R
125	*Reseda lutea*	R			
126	*Potentilla argentea*	R			
127	*Knautia arvensis*				R
128	*Torilis arvensis*			R	
129	*Verbena officinalis*			R	
130	*Tillia grandifolia*	R			
131	*Rubus caesius*	+			
132	*Carpinus betulus*	R			
133	*Cercis siliquastrum*	R			
134	*Acer platanoides*		R		
135	*Acer negundo*		+		

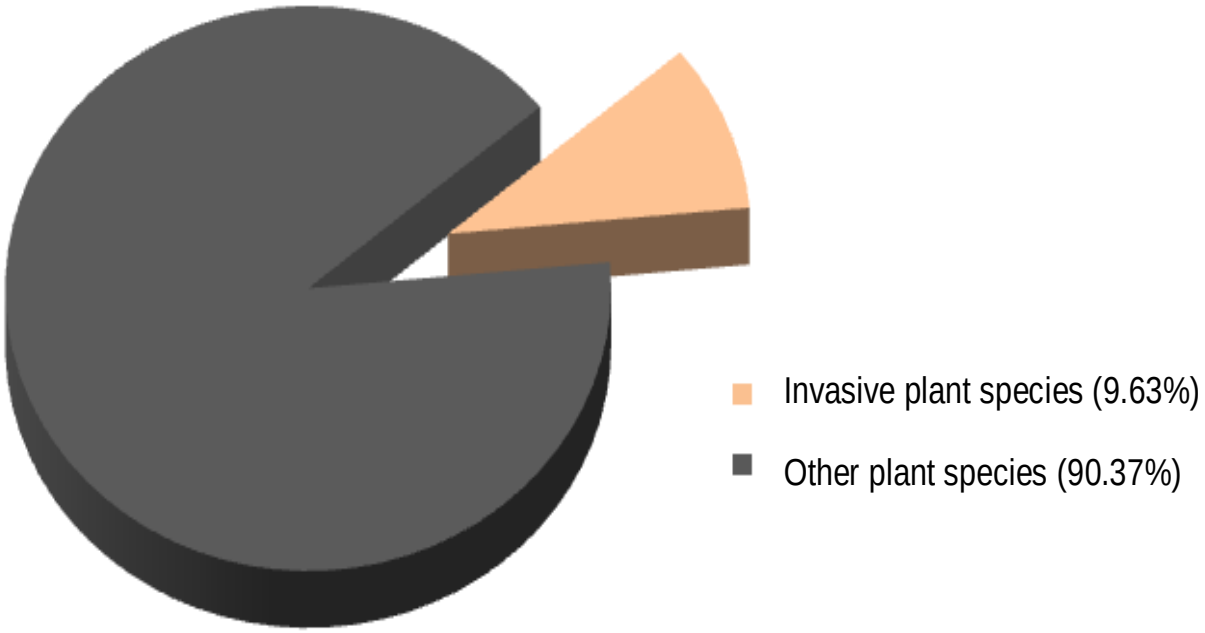

Figure 4. The representation of invasive species in lawns around highways.

DISCUSSION

Grassy spaces of roads in Belgrade were researched on 32 sites where a total of 183 plant species were recorded. The greatest number of species was found around major roads (highway) and the lowest in the lawns of traffic roundabouts. It can be said that the number of plant species in the researched categories of lawns was inversely proportional to the intensity of maintenance measures (an intensive maintenance leads to a smaller number of species in lawns.). The same happens with invasive species which increased in number as the intensity of care and maintenance decreased, that is, the number of invasive species was gradually higher going from lawns of roundabouts to lawns of highway.

Out of the total number of the recorded plant species, 18 (9.84%) species were characterised as invasive and potentially invasive. Within each type of grassy space, at least one invasive species was recorded. A large number of invasive species in grassy spaces of Belgrade roads indicates their ability to adapt to difficult environmental conditions prevailing there.

The largest number of determined invasive species belongs to the family *Asteraceae* (six species), then to the family *Poaceae* (four species), whereas the families of *Scrophulariaceae, Polygonaceae*, *Aceraceae, Fabaceae*, *Rosaceae*, *Amaranthaceae* and *Oxalidaceae* had one invasive species each.

On all the four types of grassy spaces, three invasive species were recorded: *Cynodon dactylon, Polygonum aviculare* and *Veronica persica.* These species show

Table 5. Overview of invasive plant species in road lawns in Belgrade

Species	Family	Native range	Lawn type mark where species is recorded
Elesusine indica	Poaceae	The pantropics belt	I
Sorghum halepense	Poaceae	The tropics	I
Veronica persica	Scrophulariaceae	Asia	I, II, III, IV
Polygonum aviculare	Polygonaceae	The tropics	I, II, III, IV
Artemisia vulgaris	Asteraceae	North America	I, III, IV
Cynodon dactylon	Poaceae	Africa, Asia	I, II, III, IV
Stenactis annua	Asteraceae	North America	II, III, IV
Sonchus oleraceus	Asteraceae	Euro-Asia	II, IV
Ambrosia artemisiifolia	Asteraceae	North America	III
Aster lanceolatum	Asteraceae	North America	III
Acer negundo	Aceraceae	North America	III, IV
Robinia pseudoacacia	Fabaceae	North America	III
Rubus caesius	Rosaceae	Euro-Asia	IV
Amaranthus retroflexus	Amaranthaceae	North America	IV
Oxalis stricta	Oxalidaceae	North America	IV
Bidens frondosa	Asteraceae	North America	IV
Fragaria indica	Rosaceae	Asia	IV
Bromus tectorum	Poaceae	Euro-Asia	III, IV

I=Grassy spaces of traffic roundabouts; II=the lane-dividing grassy spaces; III=grassy spaces around roads; IV=lawns of major roads/ lawns of highway.

exceptional resistance to difficult environmental conditions, particularly to shallow and compacted soil, pollutants in soil, salt, drought (Stavretović, 2008) which prevail in road lawns. Ten invasive species were recorded only on one type of road lawns. Species *Bromus tectorum, Acer negundo* and *Sonchus oleraceus* occuredr in two types of road lawns. Species *Artemisia vulgaris* and *Stenactis annua* were present on three types of grassy spaces of the roads (Table 5).

However, in the moderate continental climate conditions in Belgrade, plant species *Veronica persica* and *Polygonum aviculare* are annual plants which therefore could easily be removed from road lawns in which they are present, by using adequate maintenance measures.

Plant species *Cynodon dactylon* had the highest distribution and was proved exceptionally resistant in each researched type of road lawn, covering the largest area. Due to its resistance and perennial character, removing of *Cynodon dactylon* from the road lawns will be more difficult and should include reconstruction of the surface and obligatory further application of adequate and timely lawn care measures.

In comparison to other types of road lawns, the highest number of invasive species was recorded in the lawns of highways, which could be explained by the fact of that the lowest degree of care and maintenance was applied, as well as by the exposure to anthropogenic influence which facilitates easier distribution of invasive plant species.

Conclusion

Environmental conditions prevailing around the roads caused the occurrence of invasive species on grass spaces which surround these roads. Destruction of invasive species along roads represents an important process in stopping and controlling the spread of invasive species. Proper and timely implementation of care and maintenance measures could annul or considerably reduce the number of invasive species, whereas visual and functional characteristics of lawns could be much more pronounced.

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