EFFECTS OF MANAGEMENT AND SUCCESSION PROCESS ON THE COMPOSITION OF VASCULAR HERBACEOUS PLANT SPECIES ALONG ROADSIDE AREAS IN POLAND

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Abstract. Roadside areas are multifunctional elements of road surroundings (including their protective, socio-aesthetic and biocenotic functions). The purpose of the article was to determine the impact of management and succession process on the herbaceous species composition of expressways roadsides in Poland. The research was conducted on the roadsides of expressways (S7, S8) in the Mazowieckie voivodship and the S17 express road in the Lubelskie voivodship in Poland. Three roadside zones were identified during this study. 29 transects were distinguished, in each of them 4 phytosociological records were taken. It was done analysis of plant species composition in projects, floral analysis and plant cover, phytosociological analysis, synoptic table and DCA, life forms, effects of the different factors as roads age, slope of the slope^0, slope length on vegetation biodiversity. There were from four to five species of grass mixtures in roadside areas in the studied projects. Festuca rubra from 30% to 50% cover were dominating there. There were 116 species of vascular plants identified and they belong mostly to grasses communities such as Nardo-Callunetea (41%) and Molinio-Arrhenatheretea (31%). Mesohemerobes and perennial plants were dominating on roadside areas. Annual plants constitute 21% of the total while biennial plants as much as 5%. The age of road has got impact on decrease number of plants form the Poaceae family and when the slope length increases, the level of biodiversity of vegetation increases, too. On the basis of the analyzed cases, the mixtures used for sowing roadside slopes have a poor composition. This is an unfavorable situation that does not guarantee species stability. In order to preserve the spread of species composition, additional financial outlays and actions implementing the principles of sustainable development are necessary.
Keywords: *grasses, perennials, road surroundings, vegetation biodiversity*

Introduction

Roadside areas are elements of road surroundings and carry important functions, i.e. safety, socio-aesthetic, biocenotic, air quality and service quality (Coffin, 2007; Tong et al., 2015; Chen et al., 2019). In recent years, the expressway network in Poland has been under development. Back in 2001, there was only 401.5 km of this class of roads, in 2016 there were already 1533.9 km. By the beginning of 2018, 30% of the planned expressways had been built, which is a clear disproportion between 85% of motorways completed. This simple data analysis shows how much new space will appear in Poland in the coming years, which well need to be developed using plants. Most publications about vegetation of roadsides elaborate on, trees and shrubs (Hasan et al., 2016; McGrath and Henry, 2016; Perea et al., 2019). This is probably due to the fact that trees

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and shrubs are most easily perceived and inventoried. Despite this, herbaceous vegetation is the largest contributor to roadside coverage. Its presence is appreciated by road users, who consider it proper to move trees and shrubs away from the edge of the road to create the so-called "belts forgiving drivers' mistakes" eng. forgiving roadside (Calvi, 2015). In Poland, even if trees often occur below them, only herbaceous vegetation is found. Thus, when analyzing the layout of the expressway, it should be stated that the herbaceous vegetation covers over 50% of the area of the road. Some authors, inter alia (Forman et al., 2003; Spooner and Smallbone, 2009; Kollarou and Kollaros, 2014) have observed that herbaceous roadside herbage is increasingly appreciated.

Currently, roadside slopes are mainly covered with grasses, which are one of the most resistant to road pollution plants (Koda et al., 2010). However, they do not always withstand other adverse habitat conditions (Niemandt and Greve, 2016). In Poland, this is related with, among others, the guidelines developed for establishing and maintaining roadside greenery for the needs of the General Directorate for National Roads and Motorways (GDDKiA) (Maranda et al., 2013) in which only two out the nine species listed are legumes that can be used to complete the mixture. It should be noted that there are studies indicating that the mixtures, e.g. Medicago lupulin, Lotus corniculatus (for various purposes) should be diversified (Koda et al., 2010). Unfortunately, this solution is rarely applied in Poland. The way of carrying out maintenance works on expressways in Poland has been presented, among others in the document "Guidelines for establishing and maintaining roadside greenery for the needs of the General Directorate for National Roads and Motorways" (Maranda et al., 2013). For safety reasons, 1-3 m wide strips closest to the road are cut more often (grass height should not exceed 10 cm). For further areas, mowing 2-3 times a year is used. The grass is usually cut at a height of 5 cm. Cut grass remains on the slopes. No other care treatments such as weeding or aeration are carried out. However, there are some problems related to the GDDKiA guidelines. System changes are currently being made to allow for less frequent mowing, which results, among others, from climate change - until now contractors have been obliged to carry out the number of mowing, as a result of which work was carried out even after snowfall or in hot weather, which resulted in drying out of low vegetation. Sowing is also being slowly implemented using seed mixtures for flower meadows. Polish producers have already developed a special blend composition that allows smog reduction (so-called "anti-smog seed mix"), appreciated at the international Smogathon competition.

Expressway roadsides were chosen for research because of the technical solutions and the volume of transport routes which affect the level of arduousness of road transport on the environment (Trombulak and Frissell, 2000; Pezeshki et al., 2018; Al-Taani et al., 2019) and thus on the vegetation (Trombulak and Frissell, 2000; Truscott et al., 2005; Babcock and McLaughlin, 2011).

The purpose of the article was to determine the impact of management and succession process on the species composition of herbaceous on expressway roadsides.

Research hypothesis: The species composition of herbaceous vegetation depends on management and succession process on roadsides.

Study area

The research was conducted on the roadsides of expressways (S7, S8) in the Mazowieckie voivodship and the S17 express road in the Lubelskie voivodship in

Poland (*Figure 1*). There are two-, five- and six-year-old expressways in this area. In order to determine the research areas, the following criteria were applied: location outside of a large city, area with potential deciduous forest habitat, neighboring agricultural area (an analysis carried out at a distance of 250 m from the road, with 50 m buffer off from buildings and noise barriers). All roadsides were sown artificially to the ground. Regardless of the location and exhibition of the escarpment, a sowing standard of 25g / m^2 was used, which is in line with the rules set by most grass mix producers available in Poland. Sowing was carried out on a 10 cm thick layer of humus. The soil is sandy with thin leyer o humus along roadside.

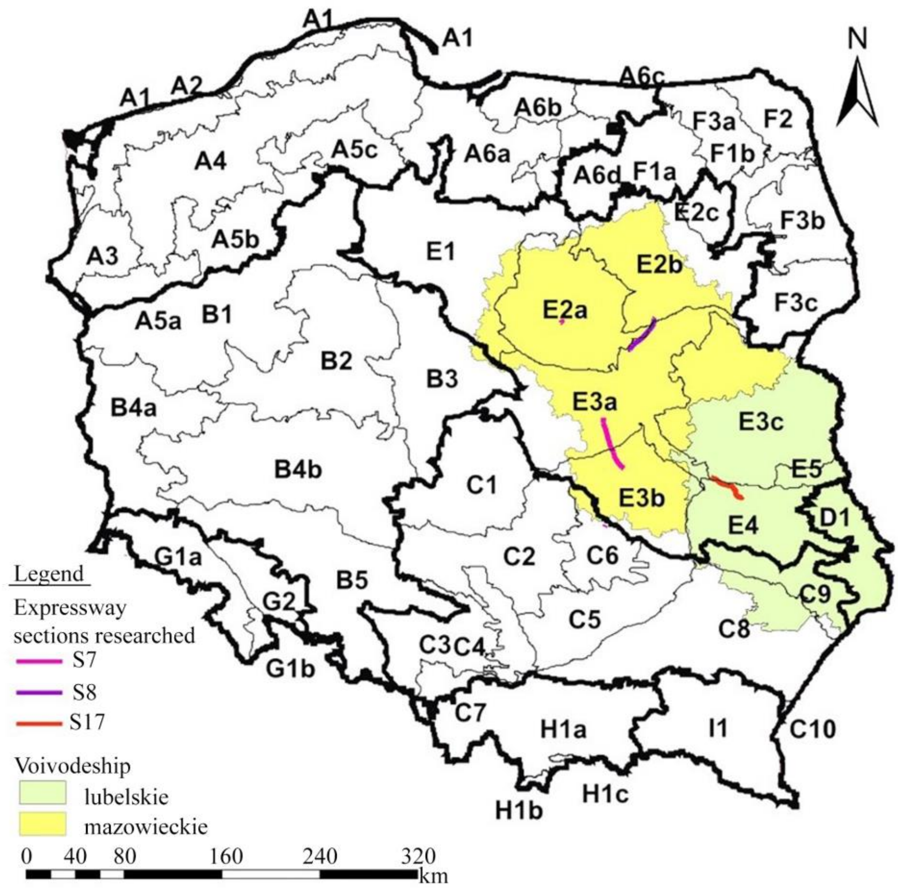

Figure 1. *Research areas against the background of voivodships, as well as divisions, lands and sub-regions in the division of Poland's geobotanical regionalization (own study based on Matuszkiewicz (1993)*

The expressways have got the roadside areas, which do not include a gravel shoulder, which could no to be overgrown by vegetation. The rest areas were diversified by plants, some parts were intensively moved, the others less moved (*Figure 2*) The slope of the slopes is wide and ranges from 1° to 50°. The lowest slope values are found on the flat surfaces behind the drainage ditch. High slope values (over 40°) occurred mainly on slopes located near road viaducts. The average slope inclination was about 32°. The greatest lengths are reached by the counter-slopes located behind the drainage ditch (length about 20 m). The average length of the slopes is about 6 m.

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***Figure 2.** View on the roadside areas (photos: M. Żołnierczuk)*

Methods and statistical approach

Research areas were designated using ArcGIS 10.5.1. At this stage, the design documentation of individual road sections was also analyzed. The composition of mixtures for sowing roadside areas available on the Polish market was carried out. Field studies were carried out and. the exact date of the survey was from 01.06. to 29.09 during the years 2016-2019.

Four roadside zones were identified during this study. 29 transects were distinguished, in each of them 4 phytosociological records were taken (one phytosociological record in each of the roadside zones). Coordnitates of research study plots (phytosociological records) were presented in *Table 1*. It was done 116 phytosociological records (one record was on 25 m^2 were taken by Dzwonko (2007)). All plants were counted on studied plot (phytosociological records).

During the research, the focus was on the roadside area, which does not include a gravel shoulder (A), which could no to be overgrown by vegetation - that's why this area (zone) was not analyzed. The research area (one transect) was divided into 3 zones, the division of which resulted from observations during pilot studies:

Zone I - a belt about 1-3 m wide, intensively mowed, for safety reasons (the vegetation must not obstruct road markings, so-called "bollards").

Zone II - the width of the third lane varies greatly and depends on the total length of the slope. It is a belt less often mowed with a uniform plant cover. Because of wider this zone, two phytosociological records were taken in this zone: the middle of the escarpment and the bottom of the escarpment at the drainage ditch.

Zone III – is located next to the drainage ditch (*Figure 3*).

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Table 1. *Coordnitates of research study plots (Geographic Coordinate System: GCS_ETRS_1989)*

Number of plots	Location	X*	Y*
1.	top of the escarpment	21.130507	52.245953
2.	middle of the escarpment	21.130521	52.245942
3.	down of the escarpment	21.130536	52.245929
4.	counterscarp	21.130546	52.245921
5.	top of the escarpment	21.131884	52.251111
6.	middle of the escarpment	21.131930	52.251104
7.	down of the escarpment	21.131964	52.251099
8.	counterscarp	21.131998	52.251092
9.	top of the escarpment	21.133623	52.254509
10.	middle of the escarpment	21.133602	52.254512
11.	down of the escarpment	21.133577	52.254515
12.	counterscarp	21.133557	52.254517
13.	top of the escarpment	21.173512	52.273265
14.	middle of the escarpment	21.173508	52.273269
15.	down of the escarpment	21.173506	52.273271
16.	counterscarp	21.173501	52.273274
17.	top of the escarpment	21.135550	52.260838
18.	middle of the escarpment	21.135539	52.260847
19.	down of the escarpment	21.135523	52.260863
20.	counterscarp	21.135514	52.260879
21.	top of the escarpment	20.230601	52.374519
22.	middle of the escarpment	20.230581	52.374512
23.	down of the escarpment	20.230561	52.374503
24.	counterscarp	20.230515	52.374488
25.	top of the escarpment	20.232107	52.364804
26.	middle of the escarpment	20.232122	52.364807
27.	down of the escarpment	20.232139	52.364809
28.	counterscarp	20.232154	52.364812
29.	top of the escarpment	21.194791	52.282403
30.	middle of the escarpment	21.194804	52.282385
31.	down of the escarpment	21.194814	52.282368
32.	counterscarp	21.194827	52.282355
33.	top of the escarpment	21.204706	52.285571
34.	middle of the escarpment	21.204734	52.285553
35.	down of the escarpment	21.204755	52.285543
36.	counterscarp	21.204777	52.285534
37.	top of the escarpment	21.243987	52.311755
38.	middle of the escarpment	21.244004	52.311746
39.	down of the escarpment	21.244020	52.311738
40.	counterscarp	21.244036	52.311731
41.	top of the escarpment	21.254634	52.320233
42.	middle of the escarpment	21.254646	52.320228
43.	down of the escarpment	21.254658	52.320221
44.	counterscarp	21.254672	52.320211
45.	top of the escarpment	21.274219	52.332497
46.	middle of the escarpment	21.274244	52.332466
47.	down of the escarpment	21.274270	52.332442
48.	counterscarp	21.274297	52.332405

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Number of plots	Location	X*	Y*
49.	top of the escarpment	21.274140	52.332554
50.	middle of the escarpment	21.274108	52.332573
51.	down of the escarpment	21.274063	52.332610
52.	counterscarp	21.274028	52.332647
53	top of the escarpment	22.132280	51.234303
54	middle of the escarpment	22.132280	51.234299
55	down of the escarpment	22.132280	51.234274
56	counterscarp	22.132281	51.234246
57	top of the escarpment	22.140240	51.233195
58	middle of the escarpment	22.140240	51.233181
59	down of the escarpment	22.140240	51.233175
60	counterscarp	22.140239	51.233167
61	top of the escarpment	22.152160	51.231525
62	middle of the escarpment	22.152160	51.231515
63	down of the escarpment	22.152159	51.231503
64	counterscarp	22.152160	51.231487
65	top of the escarpment	22.161559	51.230380
66	middle of the escarpment	22.161560	51.230374
67	down of the escarpment	22.161560	51.230369
68	counterscarp	22.161561	51.230360
69	top of the escarpment	22.210000	51.220622
70	middle of the escarpment	22.205997	51.220618
71	down of the escarpment	22.205994	51.220614
72	counterscarp	22.205991	51.220610
73	top of the escarpment	22.231346	51.193209
74	middle of the escarpment	22.231333	51.193210
75	down of the escarpment	22.231322	51.193210
76	counterscarp	22.231312	51.193211
77	top of the escarpment	22.232060	51.200227
78	middle of the escarpment	22.232051	51.200228
79	down of the escarpment	22.232044	51.200228
80	counterscarp	22.232038	51.200228
81	top of the escarpment	22.232027	51.201148
82	middle of the escarpment	22.232034	51.201150
83	down of the escarpment	22.232044	51.201152
84	counterscarp	22.232052	51.201154
85	top of the escarpment	22.212506	51.215109
86	middle of the escarpment	22.212520	51.215114
87	down of the escarpment	22.212534	51.215118
88	counterscarp	22.212550	51.215124
89	top of the escarpment	22.193357	51.223460
90	middle of the escarpment	22.193360	51.223482
91	down of the escarpment	22.193360	51.223491
92	counterscarp	22.193360	51.223501
93	top of the escarpment	22.140960	51.233188
94	middle of the escarpment	22.140968	51.233194
95	down of the escarpment	22.140978	51.233200
96	counterscarp	22.140986	51.233207
97	top of the escarpment	22.100455	51.252644
98	middle of the escarpment	22.100473	51.252652

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Number of plots	Location	X*	Y*
99	down of the escarpment	22.100487	51.252661
100	counterscarp	22.100502	51.252666
101	top of the escarpment	22.075522	51.260096
102	middle of the escarpment	22.075523	51.260098
103	down of the escarpment	22.075525	51.260101
104	counterscarp	22.075526	51.260103
105	top of the escarpment	22.085278	51.254959
106	middle of the escarpment	22.085280	51.254961
107	down of the escarpment	22.085283	51.254964
108	counterscarp	22.085285	51.254966
109	top of the escarpment	22.090353	51.254770
110	middle of the escarpment	22.090360	51.254775
111	down of the escarpment	22.090368	51.254783
112	counterscarp	22.090374	51.254786
113	top of the escarpment	22.084187	51.255277
114	middle of the escarpment	22.084196	51.255284
115	down of the escarpment	22.084205	51.255291
116	counterscarp	22.084212	51.255295

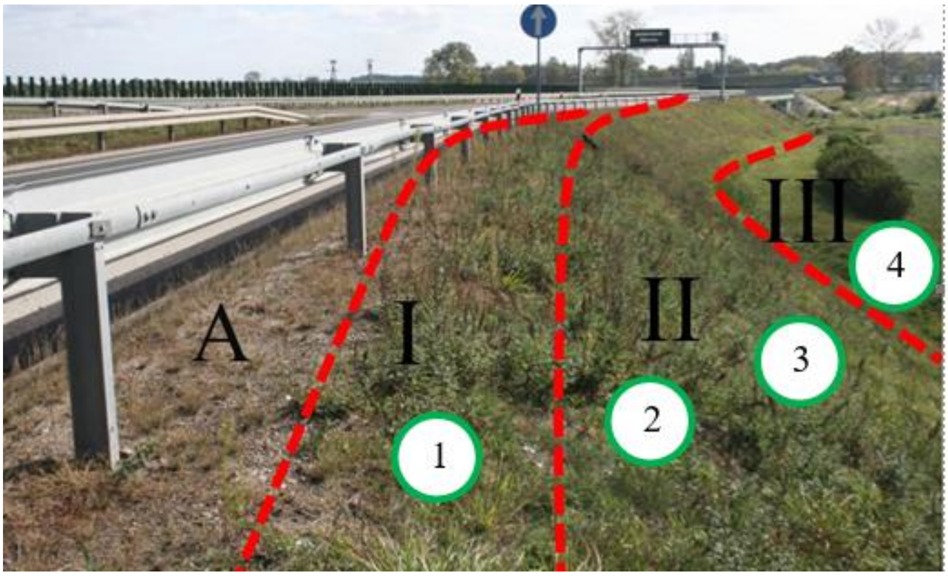

Figure 3. *Schemate of study transect: A- area (zone) not analyzed I, II, III – zones, 1, 2, 3, 4 – phytosociological records (own research)*

For the determination of plants, the key was used to identify vascular plants of lowland Poland (Rutkowski, 2004), species names were adopted after Mirek et al. (2002) and plant communities were conducted according to Matuszkiewicz (2012).

By using the 10 degree hemeroby scale (from ahemerob (natural) to metahemerobic (community completely destroyed)) there were measure a departure from naturalness. For this purpose, data from the scientific database BiolFlor were used. The Juice 5.0 program was used to determine the Shannon index (Shannon and Weaver 1963). A synoptic table was created using the TWINSPAN method - in this way, types of

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communities have been specified, characterized by different species composition. Then DCA multifactorial analyzes were performed in the Canoco 5 program - it was used to illustrate the relationship between occurring species and the age of the road. The last stages of the study are the discussion and the conclusions.

Results

Analysis of plant species composition in projects

There were from four to five species of grass mixtures in roadside areas in the studied projects. Festuca rubra from 30% to 50% cover were dominating there. Roadside sections with a majority of Festuca ovina up to 50% and Lolium perenne up to 40% were also noticed. For sowing, it was recommended to use the species indicated by the General Directorate for National Roads and Motorways. None of the designed mixtures included an extra share of other plants, e.g. papilionaceous plants. The situation is an example illustrating the state of mixtures used for sowing roadsides in Poland. Based on the carried out analyzes, it was found that mixtures containing from 3 to 7 species are available on the Polish market, with 40% being mixtures containing 4 plant species. The key species in the mixtures are the above-mentioned Festuca rubra, Festuca ovina, Lolium perenne. The Shannon biodiversity index of the analyzed mixtures ranged from 0.64 to 1.75. It should be noted that on the market there are also several mixtures of flower meadows intended for roadside areas, whose biodiversity index ranged from 2.40 to 3.8. These types of mixtures in roadside areas are applied only sporadically.

Floral analysis and plant cover

There were 116 species of vascular plants identified. The majority (91 species) were native species, whose share in the coverage of roadside slopes was 96.78% on average. The identified species belonged to 29 families, of which the Asteraceae (28 species) and the Poaceae (20 species) clearly stood out in terms of the number of species. Additionally, a relatively high share of the Fabaceae family (9 species) was recorded. The prevalence of the families mentioned above is also visible in the analysis of the degree of coverage but in this case the Poaceae family dominates (81%), Asteraceae amounts only to approximately 7%, and the Fabaceae share exceeds just over 1% (*Table 2*).

The share of other individual families was negligible and did not exceed 1% on average. Among the species from the Poaceae family, Agrostis gigantea and Agrostis capillaris clearly stood out with an average share of 26.69% and 26.32%, respectively. A high average share was also noted in the case of Lolium perenne – 16.33%, Festuca rubra – 8.23%, and Elymus repens – 5.23%. The individual share of other species from Poaceae did not exceed 4%. The average share of individual species from Asteraceae did not exceed 1.5%. The most numerous were Artemisia vulgaris (1.41%) and Achillea millefolium (1.36%). As many as 5 species are invasive species of Conyza canadensis, Erigeron annuus, Galinsoga parviflora, Solidago canadensis, Solidago gigantea, whose overall average share is 1.18%. The plant cover was about 95% - this situation was similar in the case of all roadsides, with the lowest average value occurring on the five-year-old and six-year-old roadsides where it amounted to 92% (The whole recognized plant species in each phytosociological record are in Excel file).

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Table 2a, b, c. *The average share of plant species from dominated families as Poaceae, Asteraceae, Fabaceaa on roadsides*

a,				
Poaceae	**Age of roadsides**			
Specie names	**2**	**5**	**6**	**16**
Agrostis capillaris	51.24%	10.00%	0.00%	0.00%
Agrostis gigantea	37.84%	27.45%	19.00%	42.14%
Agrostis stolonifera	49.00%	0.00%	0.00%	55.00%
Arrhenatherum elatius	10.00%	1.00%	0.00%	0.00%
Calamagrostis epigejos	0.00%	6.00%	0.00%	0.00%
Dactylis glomerata	0.00%	12.00%	7.50%	0.00%
Deschampsia caespitosa	0.00%	12.50%	0.00%	0.00%
Digitaria ischaemum	0.00%	0.00%	0.00%	2.00%
Elymus repens	15.80%	0.088	19.45%	19.00%
Festuca arundinacea	0.00%	10.00%	30.00%	0.00%
Festuca ovina	0.00%	5.00%	0.00%	0.00%
Festuca pratensis	0.00%	20.00%	0.00%	0.00%
Festuca rubra	0.00%	35.83%	41.67%	30.00%
Holcus lanatus	14.90%	0.00%	0.00%	0.00%
Lolium perenne	16.33%	11.88%	18.00%	5.00%
Phalaris arundinacea	0.00%	30.00%	15.00%	0.00%
Poa angustifolia	75.00%	22.79%	0.00%	15.00%
Poa trivialis	10.00%	0.00%	0.00%	0.00%
Setaria glauca	5.00%	2.40%	0.00%	0.00%
Setaria viridis	0.00%	9.50%	7.00%	5.00%
b,				
Asteraceae	**Age of roadsides**			
Specie name	**2**	**5**	**6**	**16**
Achillea millefolium	1.46%	3.59%	3.33%	8.29%
Artemisia campestris	1.00%	2.71%	0%	0.00%
Artemisia vulgaris	1.42%	5.63%	3.33%	5.00%
Bellis perennis	0.00%	1.00%	0.00%	0.00%
Carduus crispus	0.00%	1.00%	3.00%	0.00%
Centaurea jacea	0.00%	1.00%	0.00%	0.00%
Centaurea rhenana	0.00%	2.00%	0.00%	0.00%
Cichorium intybus	1.50%	3.00%	2.00%	5.00%
Cirsium arvense	1.25%	5.00%	3.00%	5.00%
Cirsium vulgare	0.00%	1.20%	0.00%	0.00%
Conyza canadensis	1.00%	2.00%	11.00%	5.00%
Erigeron annuus	1.00%	0.00%	0.00%	0.00%
Galinsoga parviflora	0.00%	4.00%	0.00%	0.00%
Helichrysum arenarium	0.00%	1.00%	0.00%	0.00%
Hieracium pilosella	0.00%	0.00%	1.50%	0.00%
Hieracium spilophaeum	0.00%	0.00%	0.00%	0.00%
Leontodon autumnalis	1.00%	0.00%	0.00%	0.00%
Matricaria chamomilla	0.00%	1.40%	2.00%	0.00%
Matriciara maritima	1.50%	1.50%	0.00%	3.00%
Senecio viscosus	0.00%	2.00%	5.00%	0.00%
Senecio vulgaris	0.00%	2.00%	0.00%	0.00%
Solidago canadensis	1.80%	3.50%	1.00%	0.00%
Solidago gigantea	1.00%	10.00%	0.00%	5.00%

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Sonchus arvensis	2.25%	1.80%	0.00%	4.50%
Sonchus oleraceus	1.00%	1.00%	0.00%	4.00%
Tanacetum vulgare	0.00%	5.36%	2.00%	0.00%
Taraxacum officinale	2.00%	2.40%	0.00%	0.00%
Tussilago farfara	0.00%	0.00%	0.00%	10.00%
c,				
Fabaceaa	**Age of roadsides**			
Specie names	**2**	**5**	**6**	**16**
Lathyrus pratensis	0.00%	0.00%	1.00%	0.00%
Lotus corniculatus	0.00%	1.50%	0.00%	0.00%
Medicago falcata	0.00%	2.25%	2.00%	0.00%
Medicago lupulina	0.00%	4.00%	0.00%	0.00%
Vicia cracca	1.20%	5.71%	1.67%	4.00%
Vicia hirsuta	1.50%	0.00%	2.00%	0.00%
Vicia sativa	0.00%	0.00%	6.00%	0.00%
Vicia sepium	0.00%	0.00%	3.00%	0.00%
Vicia villosa	0.00%	2.40%	0.00%	0.00%

Phytosociological analysis

Plant species belong to grasses communities such as Nardo-Callunetea (41%) and Molinio-Arrhenatheretea (31%). It was determined that 9% are accompanying species, 8% belong to grasslands, 6% are forest species, 3% of species belong to lagg, and 2% are species belonging to rushes (*Table 3*). Their distribution in land cover, however, varies depending on individual years of use. On young roadside (2 years after putting the road into service) there is a dominance of species characteristic of grasslands (47% of the area) and pastures (44% of the area). It is directly related to the selection of species of seed mixtures for sowing. Five to six years after the start of use, the share of species characteristic of pastures increases significantly (from 60% to 74%). The share of ruderal species reaching 25% and accompanying species (16%) is on the increase as well. Along 16-year-old roads, the communities stabilize further - the share of species characteristic of pastures increases (67%), the share of ruderal and associated species drops down to 18% and 14%.

Table 3. *Share of characteristic plant species (%) in different vegetation types*

Vegetation types	Share of characteristic species in %
Ruderal	41
Pasture	31
Accompanying species	9
Grasslands	8
Plantings	6
Lagg	3
Rushes	2

Synoptic table and DCA

The changes taking place in the species composition are also noticeable in the synoptic table taking into account their fidelity and frequency. TWINSPAN method and 6 groups (from A to F) were distinguished. Group C (49 phytosociological records) and

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D (47 phytosociological records) clearly stand out. In the case of phytosociological records taken along the S17 express road in the Lubelskie voivodeship, a relatively high level of homogeneity of the groups can be seen (species from group C dominate). An exemplary arrangement of groups in transects is presented in *Table 4*. Some plant species with high fidelity and frequency in the groups A –F were distinguished: group A: Artemisia campestris, Cirsium arvense, Deschampsia caespitosa, Elymus repens, Rumex thyrsiflorus, group B: Artemisia campestris, Equisetum arvense, Festuca arundinacea, Poa angustifolia, group C: Agrostis capillaris, Agrostis gigantea Achillea millefolium, Plantago lanceolata, group E: Agrostis gigantea, Daucus carota, group F: Cardamine pratensis, Carduus crispus, Festuca rubra, Hieracium pilosella, Vicia sativa (*Figure 4*).

Table 4. *Exemplary arrangement of groups in transects (own study)*

		Voivodship							
		Lubelskie Voivodeship		Masovian Voivodship					
Age of roadsides		2		5		6		16	
Location on slope	Peak of slopes	C	A	B	D	D	D	D	D
	Middle of the slopes	C	C	D	B	D	F	D	D
	Area near the drainage dich	C	C	D	B	F	D	D	D
	Counterslope	C	C	E	E	D	D	E	D

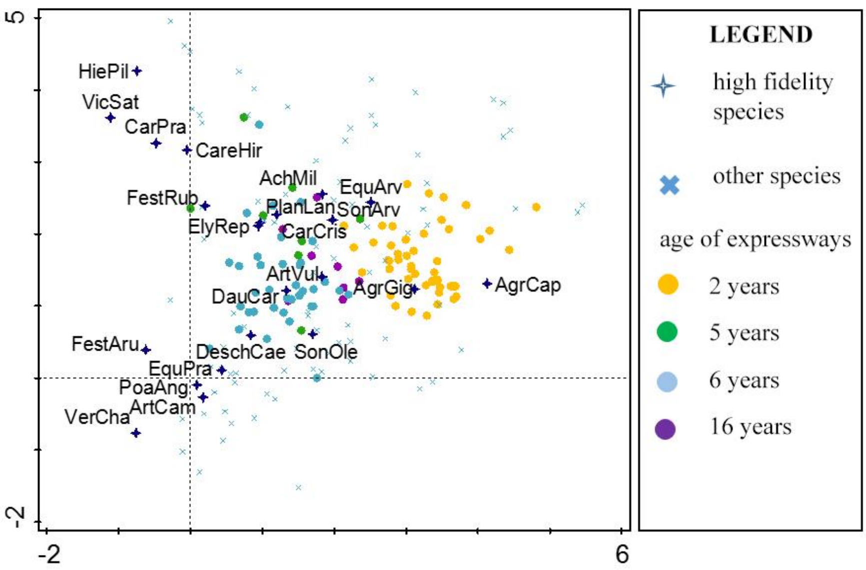

Figure 4. *Multivariate DCA analysis - relationship between species composition and road age (own research)*

Mesohemerobes plants were dominating, accounting for 25% of all plant species in general. Together with intermediate species between mesohemerobia and b-euhemerobia they constitute 47% of all species. The share of the remaining hemerobia groups was similar to each other ranging from 8% to 14%. Considering the degree of

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coverage, grades 2 and 3 (87%) dominate in the case of young roadside. On the roadsides aged 5-6 years, a-euhemerob (up to 35%) dominates. After 16 years of use, stabilization and growth of grade 2 and 3 species of hemerobia occur (49%) (*Figure 5*).

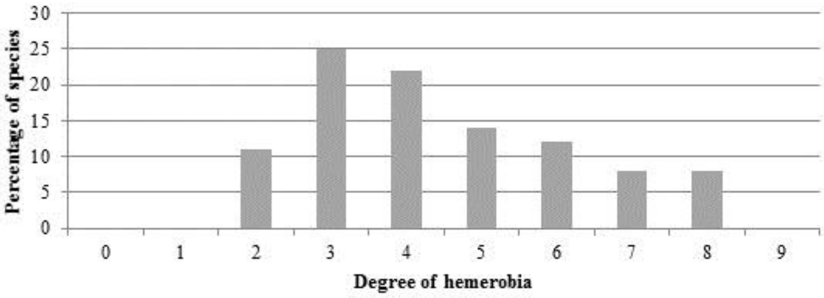

Figure 5. *Distribution of species share relative to the degree of hemerobia: 0 - ahemerob, 1 – oligohemerob (negligible human impact), 2 - intermediate form of 1 i 3, 3 - mezohemerob (moderate human impact), 4 - intermediate form of 3 i 5, 5 – b-euhemerob (strong human influence), 6*

Life forms

Perennial species are dominating (74% of the total number of species) on the studied areas. Annual plants constitute 21% of the total while biennial plants as much as 5%. When examining the degree of coverage by individual species, the dominance of perennial species is clearly visible, which on 93% of roadsides occupy 93%, five-year-old about 75%, and 16-year-old - 88%. Areas with incomplete short-circuits obtain the highest biodiversity indicators - unoccupied spots are inhabited by annual species. In places where the short circuit is greater, the value of the Shannon index decreases (r = -0,46636) (*Figure 6*).

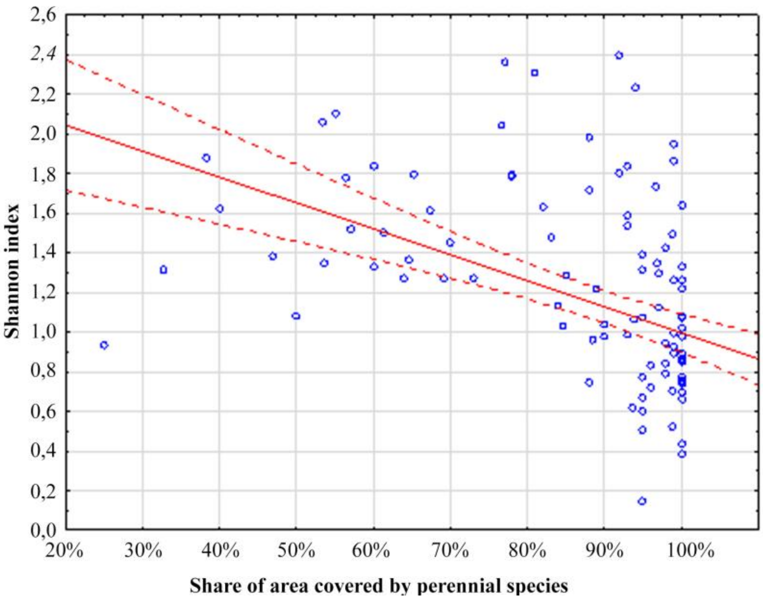

Figure 6. *A scatter chart illustrating the impact of the share of perennial species in area covered on the level of the Shannon index, r = -0,46636 (own study)*

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Effects of the different factors as roads age, slope of the slope ^{0}, slope lengt on vegetation biodiversity

In the design documentation of the analyzed road sections it was assumed that the slopes would be sown with mixtures consisting only of grasses. During the phytosociological analysis, it was found that the share of species from the Poaceae family decreases with age of the roads (*Figure 7*). The resulting spaces are inhabited during succession mainly by species from the Asteraceae family (*Figure 8*).

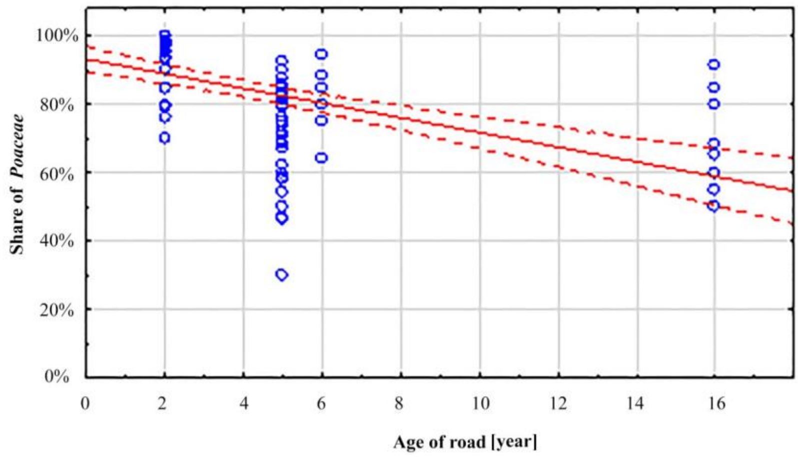

Figure 7. *Share of plant species from Poaceae depending on the age of the road. r=-,5063 (own study)*

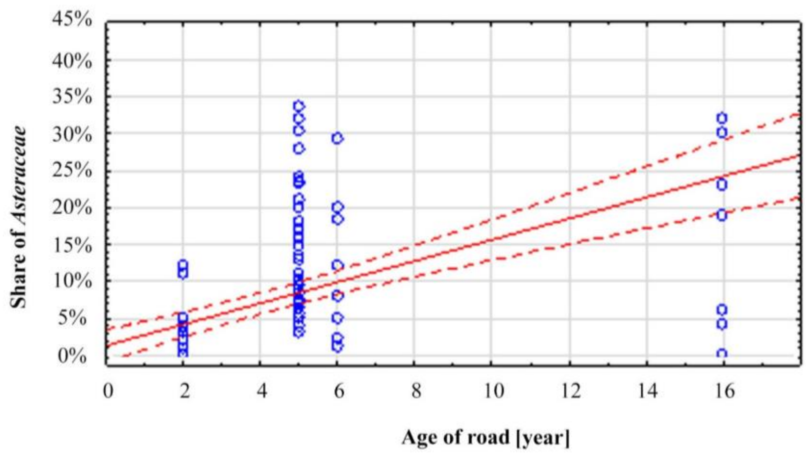

Figure 8. *Share of plant species from Asteraceae depending on the age of the road. r=-,55091 (own study)*

The analyzes show that as the angle of inclination increases, the species diversity of the vegetation decreases (*Figure 9*). This is related to, among others with higher speed of water flowing along the slopes after precipitation - an increase in water speed causes easier detachment of seeds, which together with water move towards drainage ditches.

Based on the results obtained, it can be seen that as the slope length increases, the level of biodiversity increases (*Figure 10*).

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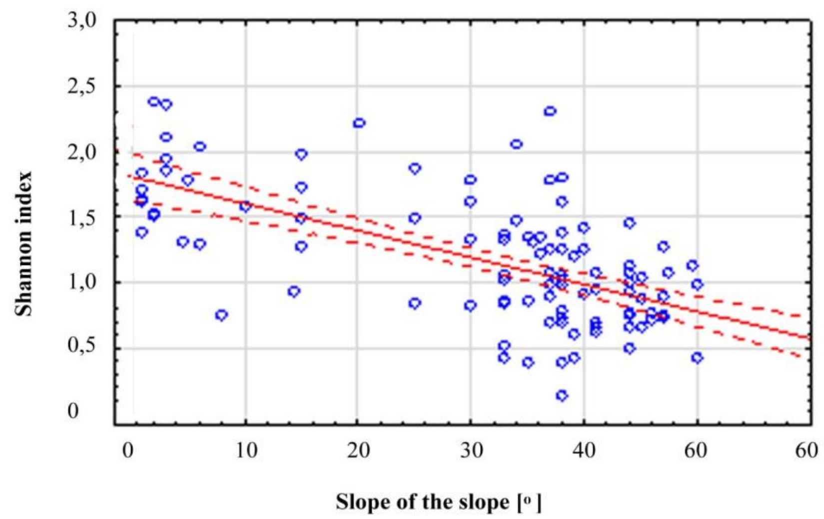

Figure 9. *Shannon index depending on slope of the slope ^{0} on the road in different ages. r=-,6085 (own study)*

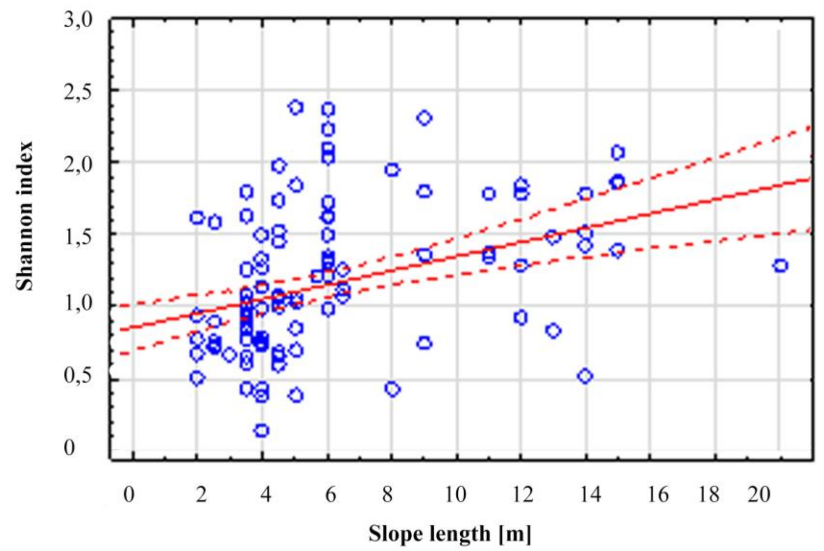

Figure 10. *Shannon index depending on slope length on the road in different ages. r=-,36855 (own study)*

Discussion

Based on the conducted research, it was found that the formulated research hypothesis was true. In the course of the study, 116 plant species were identified. This result does not differ from the results of research by other authors conducted in the studied regions (for example, Trzaskowska and Adamiec (2012) were identified 110 plant species in Lublin) but also in other climatic regions: in the research of Hayasaka et al. (2012) in Japan was noted 122 species, Zeng et al. (2011) in the Yellow River delta recognized 100 plant species, and Arenas et al. (2017) along the highway near Madrid showed the presence of 130 plant species. Slight differences that appear may be due to the fact that some of the roadside areas studied by the authors were in the early stages of use. The smaller plant cover on some stands was mainly the result of technical conditions such as: lack of soil compaction, too small layer of fertile soil, large slope without additional reinforcements (geotextile, geotextile). These were the places where progressing erosion was visible (Xiao et al., 2017).

The roadside is dominated by native species (Forman et al., 2003; Szwed and Perkiewicz, 2010) which was confirmed in the research conducted by the authors where the share of alien and cultivated species slightly exceeded 3%. Alien species are mainly ruderal species of commonly considered weeds. The adjacent roadsides can potentially promote the spread of these species, which raises farmers' concerns (Chaudron et al., 2016). Understanding the factors that shape roadside vegetation makes it possible to design programs that protect biodiversity, which limits the increase in weeds that can harm crops (Chaudron et al., 2018). The predominant share of native species is associated with the formation of corridors along the roads that allow native and alien species to move (Zeng et al., 2011; Arnadottir, 2012).

Perennial species were dominating, however, their share varies over time. Based on the conducted research, the authors concluded that the process of succession takes place over time, which is consistent with the situations described by (Wysocki, 1994). Over time, the species share may decrease by as much as 17% to 33% of land cover (Wysocki and Stawicka, 2000). A similar tendency was stated by Zeng et al. (2011). The author observed that after the initial low value of biodiversity of annual plant species, their diversity increases, which is in accordance with the view presented by Forman et al. (2003), and Pickett and McDonnell (1989). This demonstrates both the succession and competition between species. The proven dominance of perennial species confirms that they are more resistant to changes in the landscape than annual species (Linborg, 2007; Chaudron et al., 2018). The obtained test results prove the need to differentiate the species composition of roadside seeding mixtures in terms of life forms.

Mesohemerobic plants were dominating, which indicates a moderate anthropogenic impact. This proves, among other things, a small amount of care work, which is limited to extensive mowing 2-3 times a year. Minimization of outlays related to care positively effects the biodiversity of plant cover as it promotes changes in species composition and an increase in the number of species (Kull and Zobel, 1991; Bernhardt-Romermann et al., 2011).

The species composition of the roadside in the first years of use clearly differs from other years, as evidenced by the obtained test results. These results are evidence that the mixtures used and their composition require modification because the sown vegetation does not withstand difficult habitat conditions and the species composition changes.

The method of management impacts the dominance of species with a competition strategy. The method of mowing particularly influences the characteristics of plants associated with the strategy C (Klimesova et al., 2008; Chaudron et al., 2016; Fried et al., 2018). There is a high probability that a change in the composition of seed mixtures used for sowing slopes and a change in the way of vegetation care (e.g. by means of mowing) will contribute to creating a certain balance between competition, stress and disturbances enabling maintaining a high level of biodiversity (Bretzel et al., 2016).

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Conclusions

Herbaceous vegetation should be subject to rational and conscious design, constant control and care along the road lane for its proper quality and durability. These activities pose significant challenges for specialists within the realm of road problems. One of more important aspects is shaping the biodiversity of roadside spaces, which makes it possible to give them significance in the protection of native flora and fauna. Due to the direction of changes in the development of roadside space, the importance of biodiversity of herbaceous vegetation along roads will increase. One of the problems of poor vegetation associated with the appearance of areas without vegetation and progressive erosion on roadside is the manner of establishing herbaceous vegetation. As reported by Stabb et al. (2015) when selecting a seed mix, engineering constraints on roadside slopes, which are associated with specific conditions in a given area, should be taken into account as well as ensuring biodiversity. Thus, the right species selection of plants for roadside spaces makes it possible to give them importance in the protection of native flora as well as the fauna of agricultural landscapes (Spooner and Smallbone, 2009).

According to the European Landscape Convention it is necessary to take all measures to promote protection, management and landscape planning, including in roadside areas. Unfortunately, on the basis of the analyzed cases, it can be stated that the landscape's dissonance around expressways space is deepening. The mixtures used for sowing roadside slopes have a poor composition (up to 8 species). This is an unfavorable situation that does not guarantee species stability. In order to preserve the spread of species composition, additional financial outlays and actions implementing the principles of sustainable development are necessary. To promote the trend, it is advisable to diversify the composition of mixtures used in roadside areas with species from the Asteraceae and Fabaceae families. These are the species that after several years of use penetrate into empty roadside areas resulting from falling out plants that have not withstood harsh habitat conditions. In order to increase the level of biodiversity of roadside plant growing it is recommendable to apply annual and biennial species as well as ones with a high degree of hemerobia or species with a competition strategy (C). The use of these species at the time of sowing will enable integration with the surrounding space, building biodiversity as well as strengthening security, including thanks to the varied space.

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ELECTRONIC APPENDIX

This article has an electronic appendix with the basic field data.

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