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RESEARCHING THE DEGRADATION OF ROADSIDE PLANT COMMUNITIES[*]

Ganna Zhelnovach[1], Karina Belokon[2], Yevheniia Manidina[2], Inna Tkalich[2]**

[1]Kharkiv National Automobile and Highway University, Kharkiv, Ukraine
[2]Zaporizhzhia National University, Zaporizhzhia, Ukraine

Abstract

Biodiversity loss is one of the global problems of mankind. The article studies the impact of the road use on biodiversity loss and, as a result, the degradation of plant communities which occupy large areas and are the basis of ecosystem development. It is defined that they degrade due to man-made soil salinisation, physical vegetation destruction, dust and chemical pollution. The paper assesses the level of such degradation of the roadside plant community at the representative road section in terms of quantity and quality. A significant level of destructive impact has been detected which results in the loss of species composition, displacement of glycophytes by halophytes, reduction of grass density by over 70 % compared to the checkpoint as the highway nears. Practical approaches to the development and implementation of a roadside vegetation management system are proposed.

Keywords: degradation, environmental safety, highway, plant community, pollution, roadside space

1. Introduction

Among the numerous sources of pollution, road transport systems which include highways and vehicles pose the greatest danger to the environment. Such systems have a massive impact on ecosystems of all levels due to the length and branching of the road network coupled with high mobility of traffic flows and an ever-growing number of vehicles (Zhelnovach, 2010).

Today the development of road transport systems in many counties of the world, including Ukraine, does not take into account the ability of different ecosystems and their components to resist the anthropogenic load. When analysing the man-made impact, also of the road transport systems, researchers mostly consider chemical and parametric pollution

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[**] Corresponding author: email: zhelnovach.ganna@gmail.com

indicators (Plyaczuk et al., 2011; Rumiantsev et al., 2015). Yet, the issues of the integrated destructive impact on ecosystems based on the existence of phytocoenoses (i.e. plant communities within a designated geographical unit) remain neglected. It is worth mentioning that in recent decades phytocoenoses as the components of roadside ecosystems have changed mostly due to the increased highway contribution. As a consequence of highway construction and operation vegetation changes dramatically, derivative groups of plants, not typical for the natural plant communities, appear, which causes biodiversity decline (Kavtaradze et al., 1999). Against the active degradation of plant communities, the roadsides crossing different ecosystems serve as a migration corridor and can become a shelter for many grass species, including rare and endangered ones.

Thus, taking into account the global trends of the ecosystem and its component conservation in situ, the study of the degree of the natural plant community degradation in the area of highway impact as the basis for the development of a roadside vegetation management system becomes relevant for preserving biodiversity at all environmental levels.

The main objective of the paper is to determine the level of impact caused by the operation of road transport systems on the roadside plant communities aimed at increasing their environmental safety through the development of a roadside vegetation management system. For achieving this objective, the following tasks have been set:

- to identify the priority factors causing the degradation of roadside plant communities;
- to determine the degree of the roadside plant community degradation in terms of quantity and quality;
- to elaborate approaches for the introduction of a roadside vegetation management system.

2. Materials and methods

Based on the paper objective, the decision was made to study the degradation of roadside plant communities taking into account its qualitative and quantitative changes characterised by grass density and its species diversity (in terms of salt resistance). Field observation of the roadside plant communities was selected as the method.

A typical for Ukraine industrial and agricultural region, Kharkiv oblast, was selected as the research territory. The region's current state of soil biodiversity depends on a number of natural and anthropogenic factors.

There are over 150 types of soils within the Kharkiv region as it belongs to two zones – forest-steppe and steppe. Forest-steppe area is characterised by the greatest variety as there are deep black soils (Chernozem), grey, dark grey podzolic and degraded soils, podzolic and degraded black soil (Chernozem). Ordinary black soils prevail in steppe zone. The Kharkiv region is subject to regrading of soil with dark grey podzolic soils and podzolic black soils being typical there (Tymchuk, 2018).

Forb-fescue-feather grass plants are the basis of plant communities in the research territory:

- dryland cereals – *Festúca valesiáca, Stipa, Koeléria, Cirsium, Salvia L., Elytrígia répens, Verbáscum densiflórum, Échium, Bromus inermis, Festuca pratensis Huds., Leōntodon, Festuca rubra, Phléum praténse L., Prangos odontalgica, Heracleum, Agropyron desertorum, Artemísia;*
- forbs – *Trifólium, Verónica, Oríganum vulgáre, Salvia;*
- ephemeras – *Myosótis, Semolina, Adōnis vernālis, Euphórbia, Astragálus dasyánthus.*

To assess the impact of road transport systems on roadside plant communities, a representative section of the M-03 Kyiv-Kharkiv-Dovzhanskyi highway in the Kharkiv district of the Kharkiv region was selected. This highway is one of the most important through roads in Ukraine and has a high traffic load. The choice of the research territory is explained by its typicality for the region and peculiarities of the route conditions. The characteristics of the road section are presented in the Tables 1-2.

Table 1. Characteristics of the road section under research

Criterion	***Value***
Length	1 km (446+555 ─ 447+555)
Put into operation	1949-1952
Speed limit	120
Roadway width	115 m
Subgrade width	156
Fill/ditch depth	Fill ─ 2 m from both sides
Right-of-way	225 m from both sides of the roadway
Number of lanes	2
Lane width	375
Shoulder width	2 m from both sides of the roadway
Hard shoulder width	075
Longitudinal slope	0 ‰
Cross slope	20 ‰
Shoulder slope	40 ‰
Type of soil	Ordinary Chernozem soils, light loam soils

Table 2. Traffic intensity on the road section

Traffic intensity, vehicles per day			***Share of trucks and buses in the flow, %***	***Traffic intensity, vehicles per day***
cars	***trucks***	***buses***		
6955	4900	465	39.0	12320

Field observations were made in the spring and summer of 2019 according to the following requirements:

2.1. Testing site arrangement:

- testing sites were arranged at three locations along the road section of 1 km long – along the edges and in the centre of the road section,
- samples were taken at every point at distances of 3, 10, 15, 20 and 30 m from the edge of the roadway on both sides of the roadway (Fig. 1) (Kavtaradze et al., 1999) (Zhelnovach, 2012);

2.2. Sampling:

- size of the testing site 0.5×0.5 m, area 0.25 m^2 (marked by four wooden poles),
- number of testing sites – 30 pcs,
- grassland vegetation from each testing site was cut even with the ground using scissors,
- the cut grass from each testing site was placed in plastic containers bearing the sample number.

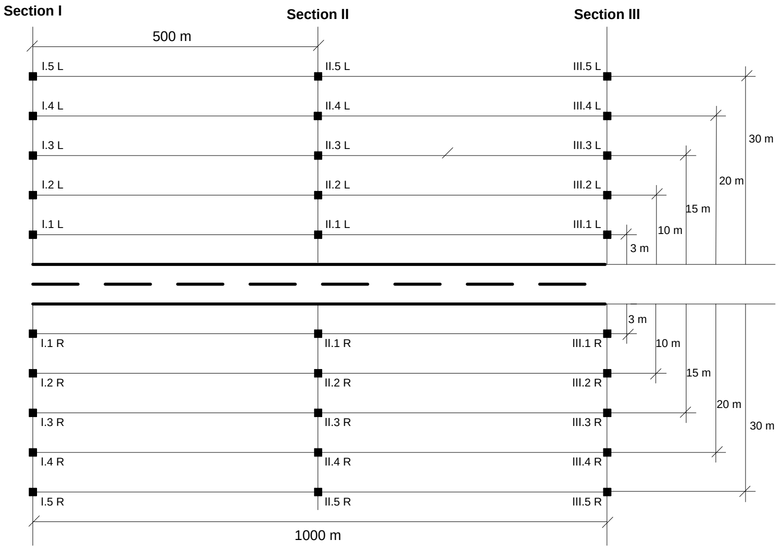

Fig. 1. Sampling procedure of roadside vegetation (L – to the left from the roadway, R – to the right from the roadway)

Qualitative changes of the roadside plant community based on its species composition were determined at the testing sites along the road section under research using established methods for each sampling according to the guide followed by averaging of the results on three sections on both sides of the road at each control distance. Quantitative changes of the roadside plant community based on grass density were determined by weighing the samples three times using electronic analytical balances Axis ANG 100C with readability down to 1 g from each testing site followed by averaging of the results on three sections on both sides of the road at each control distance (Zhelnovach, 2020).

3. Results and discussion

The theoretical analysis resulted in the conclusion that the main reasons for the degradation of roadside plant communities include:

- the salinisation of roadside soils because of deicing agents – affected by them, germination of grass decreases by 50%; the height of grass stand decreases by 5 to 10 cm with the plant cover dropping by 50% to 80%, and species diversity can reduce by up to 30 % from the natural rate. Maximum salinisation of roadside soils is observed at a distance of 3 to 20 m from the edge of the road; and generally, salinisation zone covers up to 200 m from the highway;
- vegetation destruction due to topsoil compaction, which leads to the degradation of vegetation above the soil surface, soil compaction, changes in its physical properties, biochemical and microbiological processes. The changes in physical properties include reducing pore space as a result of which water and air regimes change dramatically, anaerobiosis processes occur (growing of organisms in the absence of free oxygen), the intensity of microbiological processes decreases, root occupation in deep soil decreases, leading to vegetation suppression at all levels, vegetation density is significantly lower with bare spots appearing;
- dust and exhaust gas pollution, which results in the dehydration of the leaf surface forming a crust on them and disruption of natural metabolic processes. Dust deposits prevent photosynthesis processes while at the same time causing

absorption of infrared radiations which leads to overheating of plant leaves and upsetting the plants' water and thermal regimes;

- pollution by invasive species, i.e. dispersing of species threatening biodiversity as a result of human activity (Artamonova et al., 2010; Kavtaradze et al., 1999; Podolskiy et al., 1999; Vnukova and Zhelnovach, 2016).

Tables 3-4 and Fig. 2 show the results of field observations of the roadside plant communities in terms of quantity and quality.

Table 3. Qualitative composition of the roadside plant community

Distance from the highway edge, m	***Plant name***	***Ruderal species***	***Salt-resistance characteristics***	
			halophytes	***glycophytes***
3	Taraxacum officinale	+	+	–
	Elytrígia répens	+	+	–
	Chenopódium álbum	+	+	–
	Árctium	+	+	–
10	Leōntodon	+	+	–
	Elytrígia répens	+	+	–
	Urtíca	+	+	–
	Árctium	+	+	–
15	Elytrígia répens	+	+	–
	Leōntodon	+	+	–
20	Festuca pratensis	–	+	–
	Leōntodon	+	+	–
	Elytrígia répens	+	+	–
	Poa praténsis	–	+	–
30	Elytrígia répens	+	+	–
	Poa praténsis	–	+	–
	Árctium	+	+	–
	Agróstis stolonífera	+	+	–

Table 4. Quantitative composition of the roadside plant community

Distance from the highway edge, m	***Number of tillers, pcs***	***Weight, g***	***Density, g/m²***
3	49	484.79	1939.17
10	18	572.84	2291.36
15	29	649.62	2598.49
20	73	1016.56	4066.25
30	80	1697.66	6790.63

The analysis of the species composition of the roadside plant community at the road section under research showed that there are nine species of annual herbaceous plants 78 % of which are ruderal, i.e. weeds and other species having no high value and displacing plants natural for the plant community. This rate is very low for plant communities of the Kharkiv region. Besides, it is found out that the species composition of the plant community under research includes 100 % halophytes, i.e. salt-resistant species. It proves that the roadside soils of the road section under research have a high salinity level.

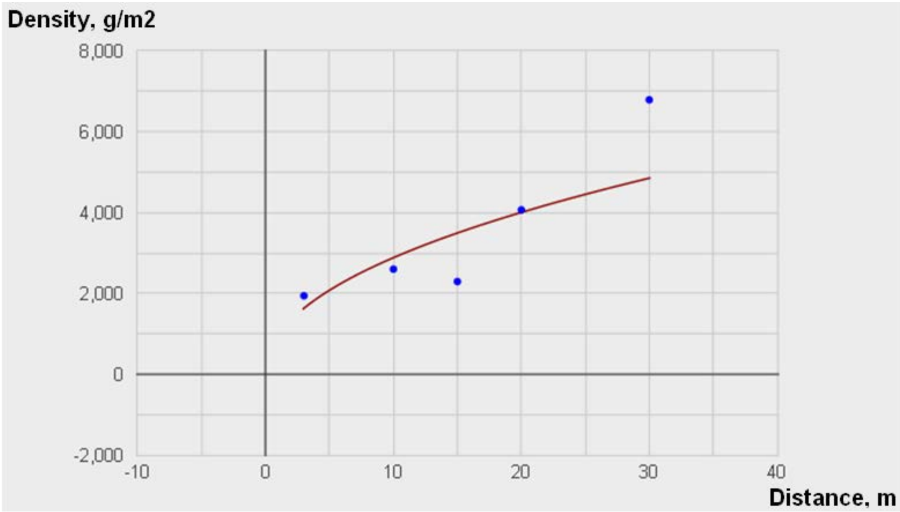

Fig. 2. The pattern of changes of grass density depending on the distance from the highway edge

The obtained data demonstrate a significant qualitative transformation of the plant community under research and its considerable suppression. Such loss of biodiversity may have happened under the influence of road transport systems since there is no other anthropogenic load on soils and vegetation of the territory under research.

Based on Table 4 a power equation showing the dependence of vegetation density from the distance from the highway edge was constructed:

$$Y = 232.3859 \cdot X^{0.4901}, \qquad (1)$$

where Y – grass density, g/m^2; X – distance from the highway edge, m (Fig. 2).

Based on the analysis of the research results (Fig. 2) a pattern of changes of grass density depending on the distance from the highway edge was found out. For the roadside plant community under research, this index increases by 71.44 % for the fifth checkpoint compared to the first one, which is high and proves that road transport systems have a significant impact on grass density of roadside areas.

Thus, the indicators of qualitative and quantitative composition of the plant community show that road transport systems have a marked impact on roadside plant communities. Since a road section typical for the Ukrainian international highways (i.e. having a high traffic load) was selected for the research, it is highly probable that such a situation is common for most roadside plant communities near highways with intensive traffic. That is why it is necessary to develop a system of specific measures to manage roadside vegetation, and it must be based on certain criteria (Fig. 3).

The main approaches allow providing provide efficient work with further implementation of the roadside vegetation management system include:

- development of project documentation for roadside greening next to highways taking into account the potential transformation of plant communities in the affected area based on the research of environmental conditions and composition of the natural plant community;

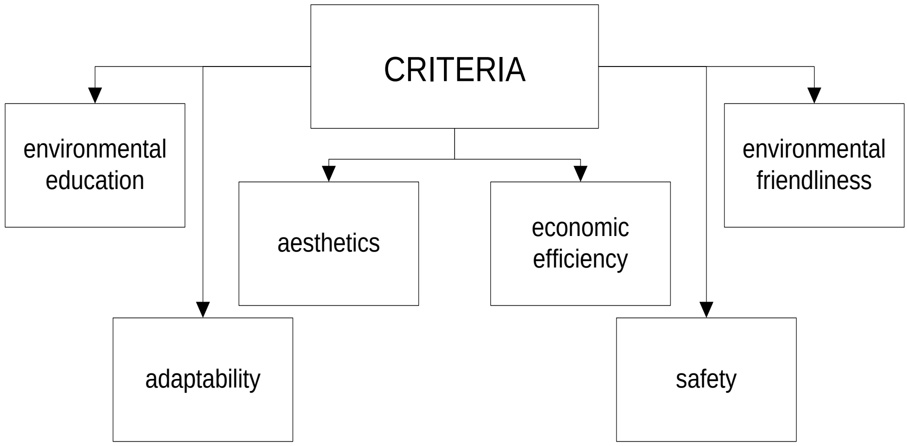

Fig. 3. Criteria for the development of the roadside vegetation management system

- selection of plant species for greening. Preference should be given to those species which were detected during the preliminary check of the area according to the greening specifications. This will allow to have better results in a shorter period of time. When greening, alien species, i.e. non-native for the natural plant community, should not be used. If such species are detected, they first should be removed from the natural plant community and only then the greening process should be started;
- creation of nature reserves or seed banks for collecting seeds and developing a network of nurseries for plant propagation and grass seed mixture production;
- conservation and promotion of roadside habitats of rare plants. If during the check populations of plants from the Red List of Threatened Species of Ukraine or some regional red lists are detected, restoration measures and management of roadside ecosystems aimed at preservation and optimization of growth conditions are required. It is preferable to have in situ conditions since only then it is possible to maintain an adequate long-term state of the population;
- maintenance and care of the green area. To ensure sustainable development of plant communities and let them conserve the plant species as homes to pollinators, insect eaters, invertebrates and wildlife corridors to rare species. Grass cutting is considered to be the main maintenance method. Thus, to ensure the growth of roadside plant communities, it is necessary to develop a grass cutting pattern taking into account the patchiness and cutting frequency to ensure pollination and further development of plant communities with different structures (Voznyachuk et al., 2019).

So, the development of the roadside vegetation management system based on the above recommendations can make the work on biodiversity conservation at the local, regional and national level more efficient, which potentially will increase the level of environmental safety of road transport systems at all levels.

4. Conclusions

The priority factors of the degradation of roadside plant communities which include soil salinisation, physical vegetation destruction, chemical and dust pollution, and plant introduction have been defined using analytical methods.

The results of the determination of the degradation degree of roadside plant communities based on qualitative indicators (salt-resistance of the plant community) show that these factors have a significant impact since 100% of the species composition belong to halophytes, and 78 % of them are ruderal plants which indicate the loss of biodiversity and transformation of the natural plant community.

The results of the field observation of the plant community transformation in terms of quantity (grass density) also prove the significance of the mentioned factors, as the density at the fifth checkpoint is 71.44 % higher than at the first one. It indicates how high is the impact highways have on plant communities.

Practical approaches allowing to develop and implement the roadside vegetation management system which include project documentation on highway network development and environmentally safe methods of biodiversity conservation have been offered.

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