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Impact of electric power facilities on natural phytocenotic diversity

Nataliia Glibovytska

PhD in Biological Sciences, Associate Professor
Ivano Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0002-6050-9664

Hanna Rashevska

PhD in Biological Sciences, Assistant
Kryvyi Rih State Pedagogical University
50086, 54 Universytetskyi Ave., Kryvyi Rih, Ukraine
https://orcid.org/0000-0001-9350-9030

Liudmyla Arkhypova[*]

Doctor of Technical Sciences, Professor
Ivano Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0002-8725-6943

Yaroslav Adamenko

Doctor of Technical Sciences, Professor
Ivano Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0001-5665-7958

Mariia Orfanova

PhD in Technical Sciences, Associate Professor
Ivano Frankivsk National Technical University of Oil and Gas
76019, 15 Karpatska Str., Ivano-Frankivsk, Ukraine
https://orcid.org/0000-0002-4931-8074

Abstract. The relevance of studying the impact of electric power facilities on natural phytocenotic diversity lies in the necessity to preserve ecosystems due to the increasing number and size of electrical facilities, which potentially can affect the functioning of natural environments. The research aims to investigate the impact of electric power facilities on species diversity. The research

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[*]*Corresponding author*

is carried out at 46 monitoring sites in the immediate vicinity of the source of electromagnetic and noise pollution within the influence of the Burshtyn thermal power plant, the Bohorodchany solar power plant, the Shevchenkove wind power plant, the Tereble-Rytska hydroelectric power plant, under regional and cross-border power transmission lines. The representation of plant species at the monitoring sites is analysed. In general, 196 plant species are identified. Herbaceous plants dominate (from 74 to 100% of all plant life forms) at all monitoring sites, except for one site. Shrubs are present in 11 monitoring sites (from 5 to 25% of all plant life forms). The trees are represented in 20 monitoring sites (from 4 to 75% of all plant life forms). 179 species belong to the first class of constancy, 12 species belong to the second class and 5 species belong to the third class of constancy (91, 6.5 and 2.5%, respectively). The last plants have been identified as indicators of the influence of power plants. The most common plant families that exist under the influence of electrical installations are established. The largest number of species is represented by *the Asteraceae*, *Rosaceae* and *Poaceae* families – 37, 19 and 15 species, respectively. The species of the third constancy class have the highest representativeness. *Daucus carota* L., *Achillea millefiolium*, *and Trifolium pratense* L. are the dominant plant species in the areas impacted by electric power facilities. 180 species belong to the first constancy class. They cannot be suitable as phytoindicators of the ecological state in the areas affected by power plants. The results can be used to develop environmental protection strategies and measures to reduce the negative impact of power generation facilities on flora

Keywords: biodiversity; constancy class; electrical power; pollution; environment

Introduction

Expanding on the relevance of studying the impact of electric power facilities on natural phytocenotic diversity is imperative due to the necessity of ecosystem preservation. Understanding these dynamics is crucial for formulating strategies to mitigate potential adverse effects on biodiversity, ensuring ecosystem preservation for current and future generations. Additionally, such research aids in fostering sustainable development practices that harmonize human activities with the natural world, promoting ecological resilience and stability.

R. Kravchynskyi *et al*. (2021) studied that plants are the primary recipients of technogenic influence, and they reflect the level of anthropogenic environmental transformation. M. Korchemlyuk & L. Arkhypova (2016) noted that the bioindicative role of plants allows timely monitoring of the smallest changes in the ecological state and, if necessary, reacting to them. Y.A. Farghaly *et al.* (2019) considered that phytocenotic wealth is the main criterion for the stability and balance of any ecosystem. The decrease in plant diversity is a sign of bioenergy resources depletion of this territory. The research conducted by L. Simkiv *et al.* (2021) underscores the significance of analysing the phytocenotic diversity of plant communities as a pivotal indicator of ecosystem ecological health. Their study delves into the dynamic interplay of structural processes within these ecosystems, offering valuable insights into fostering sustainable development practices. By elucidating these dynamics, their analysis contributes to the formulation of informed strategies aimed at safeguarding biodiversity and promoting ecological resilience in the face of contemporary environmental challenges.

The electric power industry is a source of noise, vibration, and electromagnetic environmental pollution. Understanding the impact of these pollutants on natural ecosystems is essential for assessing the overall ecological health of affected areas. U. Andrusiv *et al*. (2021) described the optimization of balance components of fuel and energy resources for organizational and economic support of energy efficiency in Ukraine. Integrating the findings of the research of V. Kopei *et al.* (2022) enriched understanding of the multifaceted interactions between industrial activities and ecological systems, aiding in the development of holistic strategies for sustainable development and environmental conservation.

Electromagnetic radiation contributes to mutation emergence caused by single-strand breaks in DNA and leads to cell division and protein synthesis disruption, especially in tissues that are actively dividing. DNA synthesis and reparation processes inhibition is observed under the impact of electromagnetic fields with a frequency of 50-100 Hz (Liu *et al.*, 2020). Changes in the diffusion rate through membranes, structures of organic compounds, denaturation of proteins owing to the absorption of thermal energy by the cell, and generation of free radicals occur under the impact of electromagnetic radiation. Free radicals are one of the ageing causes. The negative impact of noise and vibrations on the functioning of the cardiovascular, endocrine, nervous system and sensory organs of humans and animals has been defined by A. Aaron *et al*. (2019).

The functional state of plant communities under the influence of electric power facilities has not been studied. The literature sources provide data on changes in the size and shape of vegetative and generative plants' organs, and the violation of leaf asymmetry under the impact of radiation (Deruelle, 2020).

P. Bandara & D. Carpenter (2018) studied the noise influence on plants. They established that different frequencies of sound unequally influence the plants' growth. Vibration pollution affects the physiological qualities of plant seeds, which leads to their germination decrease. Optimal plant growth is observed when plants are exposed to pure tones, in which the wavelength coincides with the average main leaf sizes. The research on the phytomelioration role of woody plants under the electromagnetic radiation impact testifies about the higher plants' resistance with a large area and leaf plates' mass. The issue of the electric power industry facilities impact on natural biocenoses has not yet been studied and requires the attention of ecologists (Arkhypova *et al.*, 2021). A comprehensive study of electric power facilities' impact on plants and their cenosis within the transboundary Carpathian region of Ukraine has not been carried out.

The establishment of dominant plant species in the phytocenosis will allow informational phytoindication of the environmental state under the influence of electric power facilities. The purpose of our research is the analysis of the plant communities' species diversity under the electric power facilities influence in the Carpathian region of Ukraine. The main tasks of this article are:

- to analyse the probable impact of the electric power facilities on plants;
- to investigate the species composition of phytocenoses;
- to study the dominant plant species in the areas affected by power plants.

Materials and Methods

The methods of biological monitoring of the environmental state were used in the work: observation, surveys, and field research, which provide the description, and study of plant groups as ecosystem components in natural conditions, and research of their functioning, structure, and development (Kravchynskyi *et al.,* 2021). Field research (photo of different species), chamber work (identification of species), and analytical analysis of the results (determine constancy class) were carried out.

The research was conducted in 2021-2022 years as part of the implementation of the HUSKROUA international project on the Carpathian region territory of Ukraine in the monitoring areas under the influence of electric power facilities – transformer substations, power lines, and power plants. The monitoring network included 46 sites near the impact source. The influence zone of electromagnetic field objects can be more than 100 m (Ropyak *et al.,* 2023). The power lines create the main electromagnetic field of industrial frequency (Kusyi *et al.,* 2021). The sanitary protection zone for an overhead power line with a voltage of 1150 kV is 55 m and for an overhead power line with a voltage of 300 kV – 20 m (Ropyak *et al.,* 2023). Therefore, the research was carried out at a distance of 50 m from the source of the electromagnetic field. The level of electromagnetic and noise pollution was measured. An analysis of the species diversity of phytocenoses within each monitoring point is carried out. Plants were photographed on a test plot with an area of 25 m^2. The Plant Snap program and plant reference books were used to identify each plant species. When the phytocenosis has the form of a narrow strip (ruderal vegetation along the fence), the transects 2-2 m wide were laid. If the vegetation groups at the monitoring point were of small size (for example on wastelands), the entire vegetation centre was described. The taxonomic characteristics of each species and life form were determined according to the generally accepted method (Swaddle *et al.,* 2015). The research complied with the ethical norms specified in the Convention on Biological Diversity (1992), the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973).

The phytocenotic diversity is determined as a percentage at each monitoring site. The plant diversity in the monitoring area with the largest number of plant species is taken as 100%. The coefficient and constancy class of each plant species are determined according to the following classification (Table 1).

Table 1. The characterization of the species constancy in the phytocenosis

Coefficient of constancy	Persistence class	Representativeness of the species
81-100	V	High
61-80	IV	
41-60	III	Middle
21-40	II	
<20	I	Low

Source: J. Dengler *et al*. (2009)

The research was conducted on the territory of the Ivano-Frankivsk and Zakarpattia oblasts in the observation areas under the influence of electric power facilities – transformer substations, power transmission lines and power plants. The impact of the activity of such electric power facilities as the Burshtyn thermal power plant, the Shevchenkove wind power plant, the Bohorodchany solar power plant, and the Tereble-Rytska hydroelectric power plant was studied. Research was also conducted on the influence of overhead power lines and transformer substations of various capacities. The influence of cellular communication stations was studied within the population centres. In total, the monitoring network includes more than 250 points in the immediate vicinity of the source of influence.

Results and Discussion

The results of phytocoenotic diversity studies under power plants' impact demonstrate the following: the largest number of plant species is represented on the wind power plant territory in Shevchenkove village – 34 species (site 34) and the experimental area of Bohorodchany – 32 species (site 38). The smallest number of plant species (4 species) is represented on one of the experimental sites in Yaremche city (site 3) and the private sector territory in Tyachiv village (site 14) (Fig. 1).

The first experimental site in Yaremche city, the experimental site in Dilove village and also in Nizhnya Tisa village is characterized by high phytocenotic diversity (more than 75%). In the areas affected by electrical installations ten of the 47 identified families are the most common: *Asteraceae* – present at 45 sites, *Fabaceae* – 39 sites, *Rosaceae* – 26 sites, *Apiaceae* – 33 sites, *Poaceae* – 26 sites, *Lamiaceae* – 25 sites, *Ranunculaceae* – 24 sites, *Urticaceae* – 16 sites, *Plantaginaceae* – 23 sites, *Polygonaceae* – 17 sites. All other families are marked by a low representation in the system of biological monitoring of electric power facilities' impact – they are present in several 1 to 7 monitoring sites. The largest number of species is represented by *Asteraceae*, *Rosaceae* and *Poaceae* families – 37, 19, and 15 species, respectively (Fig. 2).

In the areas impacted by electrical installations *Lamiaceae* family is represented by 14 plant species, *Apiaceae* – 12 species, *Fabaceae* and *Polygonaceae* – 9 species, *Ranunculaceae* – 7 species. Other plant families are represented by from 1 to 5 species. Among 196 identified plant species at all monitoring sites, 179 species belong to the first constancy class, 12 species to the second and 5 species to the third constancy class, which in percentages is 91, 6.5 and 2.5%, respectively (Fig. 3).

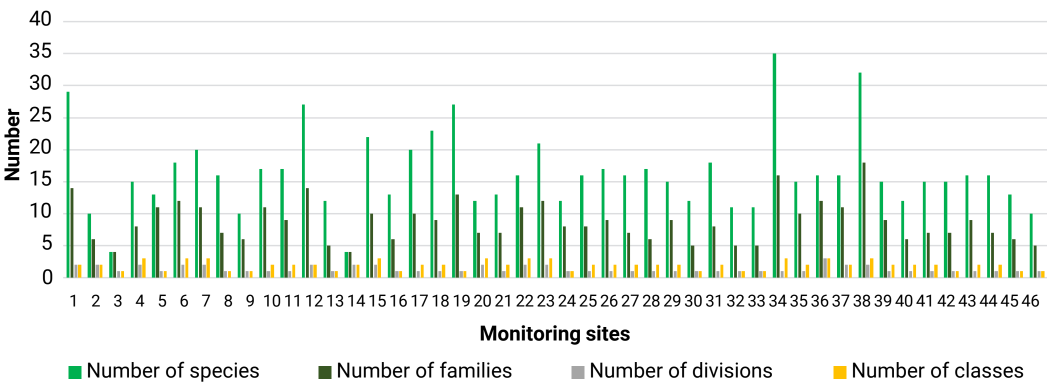

Figure 1. Taxonomic characteristics of plants at monitoring sites of electrical installations' impact on the environment

Note: site 1-5 – Yaremche, 6 – Yasinya, 7-11 – Rakhiv, 12 – Dilove, 13-16 – Tyachiv, 17-18 – Teresva, 19 – Nizhnya Apsha, 20-26 – Solotvyno, 27 – Sokyrnytsia, 28-29 – Khust, 30 – Lipcha, 31 – Nizhny Bystry, 32 – hydroelectric power station on the Tereblya River, 33 – Vyshkiv, 34-36 – Shevchenkove, 37-39 – Stari Bohorodchany, 40-46 – Burshtyn

Source: developed by the authors

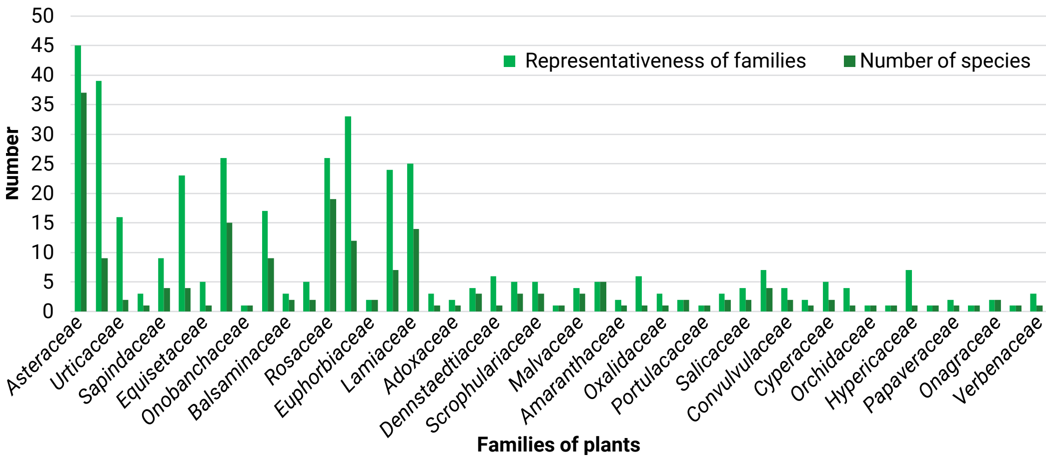

Figure 2. Representativeness of plant families at monitoring sites of electrical installations impact on the environment
Source: developed by the authors

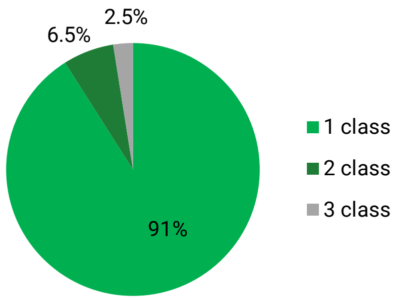

Figure 3. The percentage ratio of plant species by constancy classes at monitoring sites under electrical installations impact
Source: developed by the authors

Figure 4. *Achillea millefolium* L.
Source: photo by the authors

Figure 5. *Daucus carota* L.
Source: photo by the authors

Among 196 identified plant species, species belonging to the third constancy class have the highest representativeness – *Achillea millefolium* L. and *Bellis perennis* L. from the *Asteraceae* family, *Trifolium repens* L. and *Trifolium pratense* L. from *Fabaceae* family, *Daucus carota* L. from *Apiaceae* family. *Achillea millefolium*, *Trifolium repens* and *Daucus carota* are the dominant plant species in the areas affected by power plants, which are represented in 46, 48, and 50% of the experimental areas, respectively (Fig. 4-6).

Figure 6. *Trifolium pratense* L.
Source: photo by the authors

These plants have formed stable populations in various living conditions and are most adapted to heterogeneous habitats. Therefore, they are recommended to be used in the biological monitoring of anthropogenic influence, including the influence of electromagnetic and noise pollution, on the biotic environment (Gagliano *et al*., 2017; Mesfin *et al*., 2018).

The second class of permanence includes the following plants' species – *Taraxacum officinale* Wigg., *Centaurea jacea* L., *Plantago lanceolata* L., *Sonchus arvensis* L., *Calamagrostis epigejos* (L.) Roth., *Dactylis glomerata* L., *Ranunculus acris* L., *Mentha longifolia* L., *Tanacetum vulgare* L., *Artemisia vulgaris* L., *Urtica dioica* L. These species are represented in the amount of 20-40% of experimental points and can be used in ecomonitoring studies of electric power facilities' environmental impact (Slabbekoorn & Ripmeester, 2008).

All other species (*Urtica urens* L., *Juglans regia* L., *Acer platanoides* L., *Equisetum arvense* L., *Vicia villosa* Routh., *Molinia caerulea* L., *Aegopodium podagraria* L., *Rumex acetosella* L., *Impatiens parviflora* DC., *Festuca arundinacea* Schreb., *Rumex crispus* L., *Galium besseri* L., *Prúnus doméstica* L., *Lathyrus pratensis* L., *Phléum praténse* L., *Lactuca serriola* L., *Arctium minus* (Hill.) Bernh., *Triticum aestivum* L., *Euphorbia helioscopia* L., *Thuja occidentalis* L., *Iva annua* L., *Galinsoga parviflora* Cav., *Erigeron annuus* (L.) Desf., *Aesculus hippocastanum* L., *Cardamine pratensis* L., *Filipendula ulmaria* (L.) Maxim., *Angelica archangelica* L., *Fraxinus excelsior* L., *Eupatorium cannabinum* L., *Stachys palustris* L., *Pteridium aquilinum* (L.) Kuhn., *Salvia glutinosa* L., *Rúbus idáeus* L., *Corylus avellana* L., *Stachys sylvatica* L., *Scrophularia nodosa* L., *Ulmus alata* Miehx., *Solidago virgaurea* L., *Tilia cordata* Mill., *Plantago major* L., *Actaea spicata* L., *Torilis arvensis* L., *Verbascum thapsus* L., *Phléum praténse* L., *Bidens tripartita* L., *Anuncus dioicus* (Walter.) Fernald., *Cirsium arvense* L., *Angelica sylvestris* L., *Anemone blanda* L., *Petasites albus* (L.) Gaertn., *Rumex acetosella* L., *Capsella bursa-pastoris* L., *Persicaria lapathifolia* L., *Origanum vulgare* L., *Erigeron canadensis* L., *Rosa rubiginosa* L., *Amaranthus netroflexus* L., *Lamium album* L., *Reynoutria sachalinensis* (F. Schmidt.), *Alliaria petiolate* (M. Bieb.) Cavara, *Reynoutria japonica* Houtt., *Rumex crispus* L., *Lamium maculatum* L., *Rúbus idáeus* L., *Agrimonia eupatoria* L., *Rorippa sylvestris* L., *Polygonum aviculare* L., *Polygonum hydropiper* L., *Symphoricarpos albus* (L.) S.F. Blake, *Oxalis dillenii* Java., *Impatiens glandulifera* Royle., *Hypochaeris radicata* L., *Rosa pendulina* L., *Acer campestre* L., *Lolium perenne* L., *Solidágo canadénsis* L., *Tilia platyphyllos* Scop., *Pastinaca sativa* L., *Salvia verticillata* L., *Echium vulgare* L., *Alnus glutinosa* (L.) Gaerth., *Robinia pseudoacacia* L., *Portulaca oleracea* L., *Digitaria sanguinalis* (L.) Scop., *Picea abies* (L.) H.Karst., *Prunus cerasifera* L., *Cichorium intybus* L., *Melilotus officinalis* (L.) Pall., *Ambrosia artemisiifolia* L., *Clematis vitalba* L., *Hibiscus syriacus* L., *Salix caprea* L., *Crepis capillaris* (L.) Wallr., *Bidens tripartita* L., *Raphanus raphanistrum* L., *Gypsophila muralis* L., *Panicum virgatum* L., *Convolvulus sepium* L., *Prúnus doméstica* L., *Cynodon dactylon* (L.) Pers., *Tordylium apulum* L., *Medicago sativa* L., *Prunella vulgaris* L., *Dipsacus fullonum* L., *Acer platanoides* L., *Rosa multiflora* Thunb., *Lamium purpureum* L., *Anthemis arvensis* L., *Fraxinus ornus* L., *Prunus cerasus* L., *Rubus ulmifolius* Schott., *Jacobaea erratica* (Bertol.) Fourr., *Fructus Rubi* idaei, *Lythrum salicaria* L., *Carex flacca* L., *Poa pratensis* L., *Hieracium canadense* L., *Heracleum sosnowskyi* Manden., *Carpinus betulus* L., *Helianthus tuberosus* L., *Ranunculus repens* L., *Sambucus ebulus* L., *Galeopsis speciosa* L., *Rubus caesius* L., *Lysimachia vulgaris* L., *Stellaria holostea* L., *Stachys palustris* L., *Anthemis cotula* L., *Rosa canina* L., *Fraxinus ornus* L., *Heracleum sphondylium* L., *Jacobaea vulgaris* Gaertn., *Matricaria chamomilla* L., *Myrrhis odorata* (L.) Scop., *Salix purpurea* L., *Ononis spinosa* L., *Campanula glomerata* L., *Hypericum perforatum* L., *Argentina anserina* (L.) Rydb., *Tussilago farfara* L., *Silene latifolia* Poir., *Malus sylvestris* Mill., *Symphytum officinale* L., *Stellaria graminea* L., *Prunus padus* L., *Abies alba* Mill., *Agrostis capillaris* L., *Galium sylvaticum* L., *Astrantia major* L., *Chaerophyllum temulum* L., *Ranunculus lanuginosus* L., *Matteuccia struthiopteris* (L.) Tod., *Rumex obtusifolius* L., *Hypochaeris radicata* L., *Melampyrum pratense* L., *Pyrus communis* L., *Veronica anagallis-aquatica* L., *Persicaria hydropiper* (L.) Spac.) belong to the first constancy class and are present in less than 20% of experimental points. This makes it impossible to use them as environmental quality biological indicators.

The insignificant presence of most species on the experimental sites indicates their inadequacy to resist technogenic impact and the strict adherence of these plants to environmental conditions (in particular, the need for humidity, soil type, mechanical composition and amount of nutrients of the specific growth areas' soils). Interpopulation interactions of phytocoenotic communities affect the survival of plant populations. Therefore, a stronger plant population displaces weaker plants from the territory of existence. The insignificant presence of certain plant species in the experimental points is a sign of accidental spread by seed reproduction and wind, insects, and animals transfer to certain distances. However, this indicates the low vitality of such species.

Each plant species is limited to growth in certain specific natural and climatic conditions. Environmental factors complex (biotic, abiotic and anthropogenic) affect plants spread in natural and anthropogenically altered ecosystems. The herbaceous plants dominate in all investigated sites (except for the Tyachiv village edge site) and they make up from 74 to 100% of all life plants' forms. This is explained by the high level of herbaceous forms survival due to the structure, physiology, and individual development peculiarities. Shrubs are represented in 11 out of 46 monitoring sites, and they make up from 5 to 25% of all life forms, trees – in 20 sites and make up from 4 to 75% (Fig. 7).

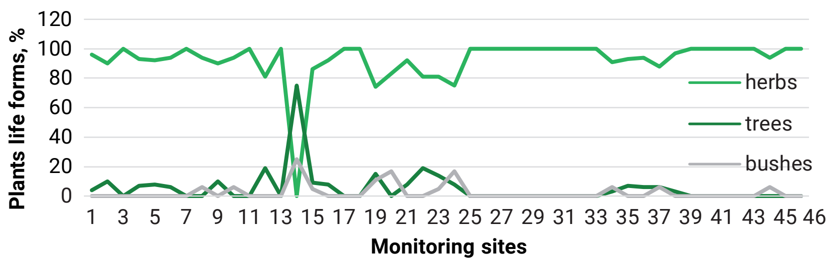

Figure 7. The percentage ratio of plants' life forms at monitoring sites under electrical installations impact

Note: site 1-5 – Yaremche, 6 – Yasinya, 7-11 – Rakhiv, 12 – Dilove, 13-16 – Tyachiv, 17-18 – Teresva, 19 – Nizhnya Apsha, 20-26 – Solotvyno, 27 – Sokyrnytsia, 28-29 – Khust, 30 – Lipcha, 31 – Nizhny Bystry, 32 – hydroelectric power station on the Tereblya River, 33 – Vyshkiv, 34-36 – Shevchenkove, 37-39 – Stari Bohorodchany, 40-46 – Burshtyn

Source: developed by the authors

In general, the average percentage value of plants' life forms in the research area is 94.33% for grasses, 12.25% for trees and 10% for shrubs.

Power generation and transmission facilities have a variety of negative effects on natural objects and biodiversity, which is associated not only with atmospheric emissions and waste generation but also with electromagnetic fields of power lines and noise impact, changes in albedo and thermal regime environment. Thus, researchers (Kopei *et al.*, 2023) conclude that the high intensity of electromagnetic fields (the experimental process is carried out at a voltage of about 1000 V and a current density of more than 500 A/m^2) causes the need to take mandatory measures to protect against harmful effects.

The destructive effect of noise on terrestrial animals is manifested at noise intensity up to 40 dB. It changes the behaviour and physiological reactions of animals. As a result, there is a decrease in reproductive potential, an increase in mortality and increased migration among animals, noted M. Havas (2017). Birds, reptiles, and amphibians are especially sensitive to noise pollution. Their range is narrowing as a result of increased technogenic activity (Garces *et al.*, 2020). Electromagnetic radiation has a similar effect on living organisms. It also has a powerful mutagenic and carcinogenic effect. Electromagnetic radiation is considered the cause of "chronic fatigue syndrome", which was diagnosed in people at the end of the 80s of the 20th century (Malovanyy *et al.*, 2022). Scientific studies of A. Wdowiak *et al*. (2017), A. Elgayar *et al*. (2019) have established several destructive processes in the human body and some animals under the influence of electromagnetic and noise pollution.

A paper by S.M. Grodsky *et al.* (2023) found that ants can serve as useful bioindicators of the severity of anthropogenic disturbances from solar energy development in deserts, and an analysis of indicators suggests that solar energy infrastructure may adversely affect some species of high ecological value (e.g., ants-reapers). The negative impacts of solar energy development on ants can have significant consequences for the functioning and integrity of a desert ecosystem, but environmentally friendly design and construction of solar installations can avoid the bottom-up environmental consequences of increasing solar energy production during the transition to renewable energy sources.

The selection of plant bioindicators of the areas affected by power plants should be carried out, taking into account climatic zoning and their phytodiversity. It is necessary to systematically conduct research and modelling (Arkhypova *et al.,* 2021).

When studying the effect of low-intensity electromagnetic radiation on insects, teratogenic effects were observed, which were inherited. In their fundamental work, G. Redlarski *et al.* (2015) have established that electromagnetic radiation leads to the delay and termination of the reproduction processes of bacteria and viruses and reduces their infectious activity. Under the influence of electromagnetic radiation in the range of 50-55 GHz, the growth of unicellular eukaryotes – yeast Saccharomyces cerevisiae is stimulated.

L.V. Kucherenko & V.S. Kalinichenko (2013) concluded that some plants, notably corn and unicellular green algae, react to definite levels of radiation by increasing growth processes. For example, the pre-sowing treatment of corn seeds by the electromagnetic field with a frequency of 3-30 MHz increases the germination energy and the laboratory similarity of the treated material. This makes it possible to reduce the growing season and increase the crop yield. At insignificant values of the electromagnetic radiation energy, a slight increase in Chlorella microalgae cells is observed. Radiation intensity increases causes the following irreversible processes of microalgae: enzymes, nucleic acids, proteins' denaturation, and destruction of cells through the appearance of the membrane pores. Electromagnetic radiation with energies above 3 kJ has a detrimental effect on Chlorella growth (Deruelle, 2020).

Researchers I.B. Korduba & Zh.I. Patlashenko (2023) has established that the unification of plant communities is observed under conditions of constant man-made influence, as a result of "ecological stress". The work of V.É. Molnár *et al.* (2020) evaluates the usefulness of the Air Pollution Resistance Index (APTI) as a composite index of the environmental condition in the city of Debrecen (Hungary). The amount of fine and coarse dust and elemental concentrations of Celtis occidentalis and Tilia × europaea were measured in June and September at three sampling sites (urban, industrial and rural) to evaluate the utility of APTI. Tree leaf APTI has been found to be a particularly useful proxy measure of air pollution as well as environmental health.

In the work of A. Cakaj *et al.* (2023), plants-bioindicators were studied for determining pollution by heavy metals in the urban and non-urban areas of Poznań. The authors conducted a study of such bioindicators as weeds: Trifolium pratense (*Trifolium pratense* L.), *Rumex acetosa* L., *Amaranth retroflexus* L., lanceolate plantain (*Plantago lanceolata* L.), ornamental Alcea species pink (*Alcea rosea* L.), *Lolium multiflora* L. var. Ponto. All species were found to have heavy metal accumulation potential, especially *A. rosea*, *P. lanceolata* and *L. multiflorum* for Zn (BCF = 6.62; 5.17; 4.70) and *A. rosea*, *P. lanceolata* for Cd (BCF = 8.51; 6.94). The translocation of Cu and Zn was most efficient in *T. pratense* (TF Cu = 2.55; TF Zn = 2.67) and *A. retroflexus* (TF Cu = 1.50; TF Zn = 2.23). It was established that the studied weeds are good bioindicators of heavy metal pollution, and their joint use makes it possible to comprehensively detect environmental threats.

The main energy facility on the territory of the Ivano-Frankivsk region is the Burshtyn TPP, which is also one of the largest sources of atmospheric air pollution. Research by H.V. Krechkivska (2022) found that within a radius of up to 500 m around the TPP there are 8 types of shrub-tree plants, deformation of shoots is observed in 75% of trees and bushes and leaf plates in 100%. This article is the closest to the research we have done. But it refers to tree-shrub vegetation, not grass.

Most plants have a high level of adaptation. At a distance of up to 1 km^2 from the Burshtynskaya TPP, there are already twenty species of shrub-tree vegetation, in which the deformation of shoots is much less and is observed in 35% of trees and bushes, but the deformation of leaf plates remains at 100%. Isolating the effects of the electromagnetic field and atmospheric air pollution on the intensity of deformation of shoots and leaf plates requires further detailed observations.

Conducted studies by S. Kaur *et al.* (2021) of physiological, biochemical and molecular changes in plant development showed that an electromagnetic field leads to a change in fermentation activity. This results in changes in plant cells and retardation of their growth. Thus, the effects of electromagnetic radiation will be integrated into the models of plant development. Therefore, the degree of soil cover by various types of plants and the degree of their overgrowth can be considered the main indicators of man-made influence. Impact zones should be characterized by an appropriate level of species and taxonomic diversity. When determining the level of pollution, it is possible to use phytoindicative scales of plant groups. At the same time, in some cases, they have a slight differentiation of values. Therefore, they are not always effective.

Therefore, the study conducted by the authors on the impact of electricity generation facilities on plant communities to use them as indicators of impact within the Carpathian region of Ukraine is original and important from the point of view of the development of ecological knowledge.

Conclusions

It has been established that under the impact of electrical installations the following plants families are the most common – *Asteraceae*, *Fabaceae*, Rosaceae, *Apiaceae*, *Poaceae*, *Lamiaceae*, *Ranunculaceae*, *Urticaceae*, *Plantaginaceae*, *Polygonaceae*, *Asteraceae*, *Rosaceae* and *Poaceae* families are represented by the largest number of species – 37, 19 and 15 species, respectively. 196 plant species are detected at 46 monitoring sites. 179 species belong to the first constancy class, 12 species to the second and 5 species to the third constancy class, which in percentages is 91, 6.5 and 2.5%, respectively. In all research sites, except for one site, herbaceous plants dominate, which make up from 74 to 100% of all life plant forms. This is explained by the high level of herbaceous forms survival due to the structure, physiology, and individual development peculiarities. Shrubs are represented in 11 monitoring sites out of 46. They make up from 5 to 25% of all life forms, and trees are represented in 20 sites and make up from 4 to 75%. The species that belong to the third constancy class have the highest representativeness. There are *Achillea millefolium* and *Bellis perennis* from *the Asteraceae* family, *Trifolium repens* and *Trifolium pratense* from *the Fabaceae* family, *Daucus carota* from *Apiaceae* family. *Daucus carota*, *Achillea millefolium*, *Trifolium repens* are the dominant plant species in the areas impacted by the electric power facilities. They are represented by 46, 48 and 50% in the experimental sites, respectively. *Taraxacum officinale*, *Centaurea jacea*, *Plantago lanceolata*, *Sonchus arvensis*, *Calamagrostis epigejos*, *Dactylis glomerata*, *Ranunculus acris*, *Mentha longifolia*, *Tanacetum vulgare*, *Artemisia vulgaris*, *Urtica dioica* belong to the second constancy class. The remaining 180 species belong to the first constancy class. They cannot be suitable as phytoindicators of the environmental condition in the areas under the electric power facilities impact.

Future research should focus on developing strategies and technologies to minimize the negative impacts of electricity facilities on natural plant diversity. This may include the development of environmentally friendly construction and operation technologies, as well as measures to restore and compensate for biodiversity losses.

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Conflict of Interest

None.

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Вплив електромагнітного забруднення на фітоценотичне різноманіття

Наталія Глібовицька
Кандидат біологічних наук, доцент
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0002-6050-9664

Ганна Рашевська
Кандидат біологічних наук, асистент
Криворізький державний педагогічний університет
50086, пр-т Університетський, 54, м. Кривий Ріг, Україна,
https://orcid.org/0000-0001-9350-9030

Людмила Архипова
Доктор технічних наук, професор
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0002-8725-6943

Ярослав Адаменко
Доктор технічних наук, професор
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0001-5665-7958

Марія Орфанова
Кандидат технічних наук, доцент
Івано-Франківський національний технічний університет нафти і газу
76019, вул. Карпатська, 15, м. Івано-Франківськ, Україна
https://orcid.org/0000-0002-4931-8074

Анотація. Актуальність вивчення впливу об’єктів електроенергетики на природне фітоценотичне різноманіття полягає в необхідності збереження екосистем через збільшення кількості та розмірів об’єктів електроенергетики, які потенційно можуть впливати на функціонування природного середовища. Мета дослідження – дослідити вплив об’єктів електроенергетики на видове різноманіття. Дослідження проводились на 46 пунктах моніторингу в безпосередній близькості від джерела електромагнітного та шумового забруднення в межах впливу Бурштинської ТЕС, Богородчанської сонячної електростанції, Шевченківської ВЕС, Теребле-Рицької ГЕС, під регіональними та транскордонними лініями електропередачі. Загалом виявлено 196 видів рослин. Трав'янисті рослини домінують (від 74 до 100 % усіх життєвих форм рослин) на всіх ділянках моніторингу, крім однієї ділянки. Чагарники представлені на 11 ділянках моніторингу (від 5 до 25 % усіх життєвих форм рослин). Дерева представлені на 20 ділянках моніторингу (від 4 до 75 % усіх життєвих форм рослин). До першого класу константності відносяться 179 видів, до другого – 12 видів, до третього – 5 видів. Останні рослини були визначені як індикатори впливу електроенергетики. Встановлено найпоширеніші родини рослин, які існують під впливом електроустановок. Найбільшу кількість видів представлено родинами складноцвітими, розоцвітими та злаковоцвітими – 37, 19 та 15 видів відповідно. Найбільшу репрезентативність мають види третього класу константності. *Daucus carota* L., *Achillea millefiolium*, *Trifolium pratense* L. є домінуючими видами рослин на територіях впливу об'єктів електроенергетики. *Taraxacum officinale* Wigg., *Centaurea jacea* L., *Plantago lanceolata* L., *Sonchus arvensis* L., *Calamagrostis epigejos* (L.) Roth., *Dactylis glomerata* L., *Ranunculus acris* L., *Mentha longifolia* L., *Tanacetum vulgare* L., *Artemisia vulgaris* L., *Urtica dioica* L. – рослини другого класу константності. Решта 180 видів належать до першого класу константності. Вони не можуть бути придатними як фітоіндикатори екологічного стану в зонах ураження електростанціями. Отримані результати можуть бути використані для розробки природоохоронної стратегії та заходів щодо зменшення негативного впливу об'єктів електроенергетики на рослинний світ

Ключові слова: біорізноманіття; клас константності; електроустановки; навколишнє середовище