

## Rare steppe plant communities in Ukraine: Status, threats and their minimization

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Nowadays, the impact of anthropogenic activities on natural vegetation is constantly increasing, the level of threats is raised, and newer risk factors are emerging. Recent trends in the anthropogenic impact on plant communities are extremely pronounced, especially on those listed in the Green Book of Ukraine (GBU). Identifying such trends is required for the further development of strategic and tactical planning for the preservation and restoration of rare grass, shrub, and subshrub steppe, petrophyte and psammophyte plant communities of the steppe and forest-steppe zones of Ukraine. In addition to well-established threat factors that cause changes in the habitat of plant communities or mechanically affect plants, new specific threats occur. Today, the most important among them in Ukraine are as follows: climate change, military activity, growing population in the industrial cities, population poverty and government corruption, changes in forms of land ownership and the creation of a land market, lack of knowledge and effective policy, including lack of popular scientific information about the status of specific species and plant groupings, inadequate management of protected areas, uncoordinated environmental protection measures, ineffective sanctions, insufficient monitoring of the consumption of natural biological resources. The preservation of rare grass, shrubby and subshrubby communities in the steppe zone of Ukraine should be provided with proper support at the state level. There is a pressing need for a law of Ukraine “On the preservation of the steppes in Ukraine” and this will require mechanisms for its implementation. The issue of developing a strategy for the conservation and balanced use of steppe ecosystems in Ukraine, whose area is one of the largest in Europe, has long been raised. The main goal of the strategy is the actual preservation of steppe communities (most of which are currently rare) ensuring their restoration, minimizing degradation, and stopping biodiversity loss. In order to develop specific actions to eliminate threats or reduce their impact on rare plant groupings, it is required to investigate the causes of threats and assess their level and duration. This is required to preserve the landscape and biotic diversity in the steppe zone of Ukraine.

**Keywords:** grass; shrub rare communities; subshrub rare communities; biodiversity; steppe zone of Ukraine; threats.

### Introduction

The interest of the presented research lies in the integral assessment of the harmful impact of historical and recent anthropogenic factors on steppe ecosystems of pan-European environmental and scientific significance. There is a need to inform the international community about the state and specific risks for rare steppe phyto-systems, in particular in the zone of military operations which qualify as a continent-level crime of the 21st century against the environment.

With the increasing impact of anthropogenic activities on natural vegetation, the level of threats is constantly increasing and newer risk factors are emerging. Research on the latest trends in anthropic influence on plant communities, in particular those listed in the Green Book of Ukraine (Didukh, 2009) is required for further development of measures for their preservation.

The anthropic impact on natural vegetation (in particular in the steppe zone of Ukraine) is constantly increasing, the level of threats is growing, and new risk factors are emerging. Identification of such trends is necessary for the further development of strategic and tactical planning for the conservation and restoration of rare grass, shrubby and subshrubby steppe, petrophytic and psammophytic plant communities in the steppe zone of Ukraine. In addition to well-established threat factors that cause changes in the habitat of plant communities or mechanically affect plants, the latest specific threats are emerging. Today, the most important among them in Ukraine are as follows: military activity, climate change, industrial production, changes in land ownership, lack of information on the status of

certain species and plant communities, adventization of alien flora, inadequate management and monitoring of the environment.

The term “threat” reflects the possibility of certain conditions emerging of a technical, natural, economic or social nature at which unfavourable events and processes may occur; this term has recently been often used in the study of environmental safety issues. The literature sources contain a definition of the term “threat” as a natural or anthropogenic phenomenon with predictable but unmanageable unfavourable events that at a certain time point can harm people's health, cause material damage or environmental destruction (Dudkin, 2003).

The total area of steppe ecosystems at the beginning of the 21st century was below the limit of the minimum allowable territory required for self-renewal and preservation of the gene pool of the entire steppe biota. The ecological structure of the remaining steppe ecosystem is significantly damaged; its area are so small that it can no longer expand into fallows, and adventive flora and fauna invade the last remnant steppe habitats.

### The main threats to rare steppe communities

The steppe zone occupies about 40% of the total geographic area of Ukraine (Fig. 1). Watershed steppe areas are ploughed here, except for nature reserves. Therefore, native steppe vegetation is localized within small-contouring remains along the slopes of river valleys and gullies where it undergoes significant anthropogenic impact and degradation.

In 2019, Ukrainian botanists first published “Prodrome of the vegetation of Ukraine” (Dubyna et al., 2019a). The book is a complete critical summary of vegetation syntaxonomy based on the principle of the ecological-floral approach (Braun-Blanquet). It reflects the current state of vegetation classification in Ukraine. The Prodrome aims to achieve the standardization of classification in Europe, promotion of natural resource management, land planning, education, and environmental policy implementation. The book describes the history of the development of this scientific direction in Ukraine, and considers the features of the highest-ranked classification units in comparison with Central and Western European ones.

The classification scheme is presented, which includes 1009 plant associations belonging to 252 unions, 127 orders, and 75 classes. A characteristic was given for each syntaxon: name, synonyms, diagnostic species, environmental conditions, distribution in Ukraine, synsociological status, and literature sources. The rarity component includes 145 associations (15% of the total number) that belong to 38 classes. Among the individual classes, the largest number of rare syntaxa is represented by the classes *Festuco-Brometea* (26 associations or 17.9% of the total number of rare associations), *Carpino-Fagetea* (13 or 9.0%), *Drypidetea spinosae* (8 or 5.5%). Most of the rare syntaxa are represented in the composition of steppe vegetation.



Fig. 1. The boundaries of the Steppe zone on the map of Ukraine

The methodology for determining phytocenotaxonomic diversity of rarities is based on the syntaxon inventory method and the matrix method of synphytosociological assessment of the phytocenofund (Didukh, 2009). Syntaxa names were represented in accordance with the rules given in the draft “The Code of Phytocenological Nomenclature of Ukraine” (Ustylenko & Dubyna, 2015).

Rare grass and shrubby steppe communities are characterized by the richest phytocenofund. They belong to 37 associations, 17 unions, 10 orders, and 7 classes (*Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947, *Festucetea vaginatae* Soó ex Vicherek 1972, *Sedo-Scleranthetea* Br.-Bl. 1955, *Festuco-Puccinellietea* Soó ex Vicherek 1973, *Rhamno-Prunetea* Rivas Goday et Borja Carbonell ex Tx. 1961, *Drypidetea spinosae* Quezel 1964, *Erico-Pinetetea* Horvat 1959). The rarest associations confined to rare biotopes and distributed in limited areas are *Bromopsis tauricae-Asphodelinetum tauricae* Didukh et Mucina 2014, *Paronychio cephalotae-Onosmatetum polyphyllae* Korzhenevsky et Ryff ex Ryff 2018, *Asphodelino-Juniperetum foetidissimae* Didukh 2003, *Ranunculo zapalowiczii-Helictotrichonetum desertori* Kukovitsa et al. ex Kukovitsa in Solomakha 1995, *Stipo brauneri-Bromopsietum cappadocicae* Kolomyichuk et Vynokurov 2016, *Genisto albidae-Stipetum lithophilae* Didukh et Mucina 2014, *Poetum versicoloris* Kukovitsa et al. 1992, *Minuartio auctae-Festucetum pallentis* Onyshchenko 2001.

Now, most of the rare steppe communities are located in the zone of combat operations and occupation. At the beginning of the war, natural processes in rare plant communities were generally well-established and fairly predictable. Most rare communities are characterized by an extremely high-level of sensitivity to various factors and a high risk of their disturbance as a result of new interventions. The destruction of the basic components in phytocenoses as a result of military operations has resulted in their crisis or loss. Unlike plant species, phytocenoses do not reproduce their own kind but are aimed at developing the next stage. It is predicted that new successions will be overlapped with pre-war ones. This will lead to the possibility of the development of new and still unknown and unexpected changes in ecosystems, changes in the number of both individual native and invasive species, changes in dominance in phytocenoses, and the emergence of a significant number of new and transformed plant commu-

nities. There is a high probability of losing numerous communities, primarily those that are environmentally vulnerable. In the world, there are different methodological approaches to assessing biodiversity threats (Dudkin, 2003). However, there is no universal generally accepted method of such an assessment, since each threat carries many parameters or indicators of impact the assessment of which is quite subjective.

In addition to well-established threat factors that cause changes in the habitats of steppe plant communities or mechanically affect plants and their groupings (such as climate change, destruction of the steppe territory by economic activity, expansion of adventive and invasive species and their replacement of rare plant species), the latest specific threats appear, as a transformation of steppe ecosystems as a result of military operations (Table 1).

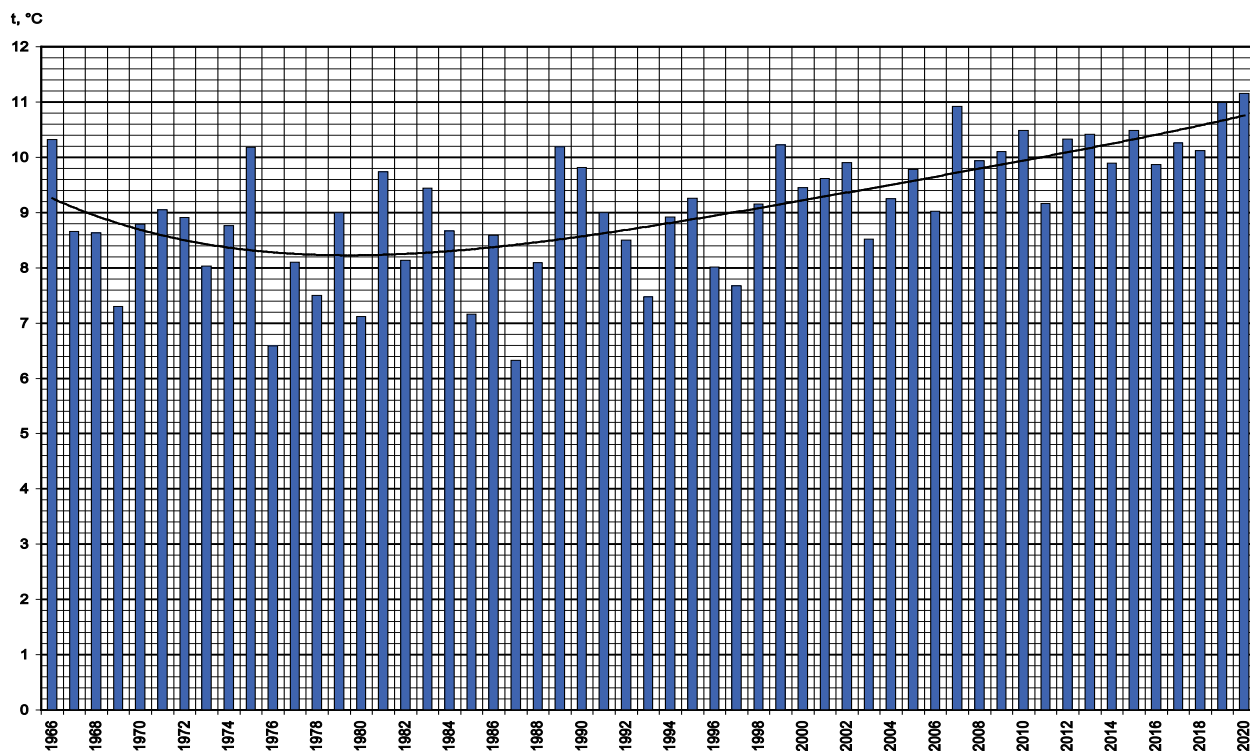
Global climate change that has occurred in recent decades causes a certain transformation of the natural environment which directly or indirectly affects the diversity of plants, their functioning and the structure of communities.

Global warming is particularly noticeable in arid and subarid regions. For example, the air temperature within the northern steppe subzone tends to increase constantly (according to the Dniprodiprovodgosp Institute). In 54 years, temperatures in this region have increased by almost 2 °C (Fig. 2). During this time, the annual course of air temperatures has retained its main features on a monthly basis. From the 1990s to the present, there has been an increase in temperature throughout the year. But the temperature increased most significantly in winter and summer periods.

This is essential for the distribution of adventive species from their southern ranges as part of steppe rare cenoses. The negative results of climate change are already noticeable in Ukraine causing significant damage to the environment (catastrophic floods, fires, flooding, dehydration, xerophytization, salinization, adventization of flora, etc.). This will lead to significant changes in the functioning of ecosystems, and primarily their plant units. The threats associated with climate change are global and, to prevent them, qualitatively new approaches to saving the biosphere based on a deeper understanding of natural processes should be introduced. A national strategy and action plan are required to preserve native vegetation, taking into account climate change.

**Table 1**  
The main established and latest threats to rare steppe communities

Threat	Causes of threat occurrence	Object of threat influence	Consequences of threat, the level of impact, and the direction of its spread	Ways to overcome the consequences of threats
Climate change	Global warming	Theoretically, all steppe ecosystems	Changes in the functioning of ecosystems and, first of all, their plant unit: fires, xerophytization, salinization, adventization. The level of influence is high, sometimes critical. Changes in the dominant phytocenoses, reduction of the rarity component, ruderalization, adventization of flora	A national strategy and action plan are required to preserve native vegetation, taking into account climate change
Transformation of steppe ecosystems as a result of military operations	Military operations	Almost all steppe ecosystems in the war zone and local steppe ecosystems in other territories	Disruption of ecosystems in the regions of the East and South. Military operations in eastern Ukraine from 2014–2023 have increased the environmental danger of the already depressed region. Destruction of vegetation, pollution of air and fertile soil layer. The level of influence is high, sometimes critical. The environmental consequences of military operations are catastrophic. It is distributed in the territories covered by military operations and adjacent areas	Introduce regular comprehensive environmental monitoring of the state of the surrounding natural environment to assess the environment transformation in reference (model) sites affected by military aggression after the liberation and complete demining of these territories
Destruction of steppe territories covered with native vegetation caused by economic activity	Intensification of agriculture (in the pre-war period). Ploughing of virgin land plots, afforestation of steppe areas. Incomplete environmental regulation, insufficient monitoring and control	Steppe biogeocenoses	Destruction of natural steppe communities, in particular, those included in the Green Book which require priority protection. The level of influence is high, sometimes critical. The threat manifests itself at all levels and should be regarded as irreversible, as it leads to the fragmentation and destruction of native steppe ecosystems and their biodiversity	Improvement of environmental and land regulation, taking into account ecosystem services of natural lands and their scientific and environmental significance. Dissemination of popular science information about the status of specific species and plant communities among the population, etc.
Expansion of adventive and invasive species and their replacement of typical zonal and rare plant species	Expansion of adventive species by various routes (road, rail, etc.) which increases as a result of military operations	Composition and structure of steppe phytocenoses	The threat exists with the development of civilization, but its level of influence has increased in recent decades due to global warming and military operations	Further improvement of environmental and land legislation. Control over the spread of adventive and, especially, invasive species. Creation of regional lists of adventive and invasive species with recommendations to restrict their expansion



**Fig. 2.** Increase in annual temperatures in the Northern steppe subzone (according to data provided by the Dneprodiprovodkhoz Institute)

Global climate change contributes to a significant transformation of natural ecosystems (Lavergne et al., 2010). The effects of climate change in the modern period acquire global significance and threaten biodiversity (Bowler et al., 2017; Gallardo et al., 2017; Harrison, 2020). Global warming in many territories, especially in Eastern Europe (Lindner et al., 2014), has two implications for vegetation cover: an increase in average annual, spring-summer temperatures, and an increase in precipitation. Annual precipitation in the region tends to increase. Over 50 years of

observation, the increase in precipitation on the territory of the Northern steppe subzone ranges 35 to 107 mm according to various weather stations, and on average is 74 mm. This, on the one side, contributes to better plant viability, and on the other side, to the spread of many adventitious species.

Boychenko et al. (2018) provided data on certain climate changes in the territory of the climatic and landscape zone of the Azov Sea region in the 20th century and at the beginning of the 21st century, namely: an

increase in the average annual temperature by  $0.8 \pm 0.2$  °C over 100 years, a significant increase in temperature during the cold period, an increase in the annual amount of precipitation by 5–10%; aridization of climatic conditions during the warm period of the year; an increase in the frequency of periods with abnormally high temperatures in winter and a significant decrease (by 15–20%) in the annual amount of precipitation in summer.

Our studies of the steppe vegetation on the slopes of the Kuyalnik Estuary valley have revealed an increase in the last 10 years of its desertification processes due to the complex action of climatic (global warming) and anthropic (pyrogenic, pastoral, etc.) factors (Dubyna et al., 2019b).

Considering further global warming, Ukraine has developed several scenarios for possible regional climate changes (Stepanenko & Polovyi, 2015). In general, in the north part of Ukraine, an increase in water resources was predicted, and in the south part, conversely, a significant reduction in them; for example, a decrease in water resources by 60% was forecasted in the Odesa region; it will lead to an increase in the frequency of droughts, dust storms, abnormal temperature manifestations, etc. Changes in the agroclimatic conditions of crops growing in Ukraine are also predicted due to expected climate changes. The area of the unstable moisture zone (forest-steppe zone) is decreased, and the arid zone (steppe zone) is increased. All climatic subzones are shifted by one towards the North. In the Southern Steppe, conditions will correspond to the moderately hot subzone of the subtropical zone (Stepanenko & Polovyi, 2015). Such a shift in the zones will lead to significant changes in natural vegetation.

Tkachenko & Boychenko (2017) believed that steppe landscapes undergo hydrogenic transformation at the present stage of adaptation of the steppe to the conditions of global warming. As a result, the mesophytization of steppe ecotopes is substantially increased affecting significantly the pedosphere. Changes begin with the expansion of long-rooted and root-growing cereals and end with the invasion and threshold saturation with steppe and forest shrubs and trees. However, all these processes were studied within protected areas in the absence of regulatory measures, and they are a result of steppe self-development and not the influence of global warming. In addition, the researchers themselves claim that if the level of global warming reaches  $3.5 \pm 0.5$  °C, on the contrary, the share of the xeromorphic component in the structure of steppe phytosystems will be increased substantially, up to the manifestations of desertification in these regions. The latter fact is confirmed by expert estimates which indicate an increase in climate aridity during the active vegetation season of the year in territories which previously belonged to areas of sufficient moisture.

Destruction of steppe ecosystems in the region has intensified unacceptably as a result of military operations, first in the east of Ukraine in 2014, and since 2022 in almost the entire steppe zone. Military actions and political instability have led to a significant negative impact on natural ecosystems, both in the territories of the Nature Reserve Fund (NRF) and beyond their borders in the conflict zone and in the surrounding areas. Currently, the destruction of landscapes, vegetation, fertile soil layer, and chemical and radiation contamination are observed there. All this will have irreversible consequences.

To overcome the consequences of the impact of military operations, it is required to introduce regular comprehensive monitoring of the state of the natural environment in reference sites affected by military aggression after the liberation and complete demining of these territories. These reference sites should include the territories of nature reserves of various ranks: the Black Sea Biosphere Reserve, the Askania Nova Biosphere Reserve, the Luhansk Nature Reserve, the Ukrainian Steppe Nature Reserve, the National Nature Parks “Nizhnedniprovs’kyi”, “Dzharylgatskyi”, “Dvurechanskyi”, “Sviati Hory”, “Meotida”, “Azov-Sivash”, “Oleshky Sands”, “Biloberezhia Sviatoslav”, “Velykyi Luh”, Regional Landscape Parks “Seymskiy”, “Kramatorsk”, “Velykyoburluk steppe”, “Pecheneg Field”, etc., including local objects (if available), such as numerous nature reserves, protected ravines and sites of nature.

Such monitoring will be aimed at assessing environmental pollution with chemicals and heavy metals as a result of shelling, establishing the presence of fires in these areas during military operations, analyzing the state of biodiversity, and comparing it with pre-war indicators. In the territories of high-ranking nature reserves (Natural and Biosphere Reserves and National Nature Parks), such monitoring should be organized by employees of the scientific departments of these institutions with the possible

involvement of specialists from the institutions of the National Academy of Sciences of Ukraine, while in the territories of lower-ranked objects it should be performed at the request of the heads of local territorial communities or land users with the involvement of the required specialists of biological and environmental profile.

A review of publications (Diakov, 2016; Lisova, 2017; Vasyliuk et al., 2017) showed that the negative impact on steppe ecosystems is caused by a complex of factors: deliberate arson which leads to large-scale fires, explosions of shells and mines, construction of trenches and other fortifications, physical and chemical pollution, as well as illegal ploughing of territories and construction of various objects. The termination of the activity of the administrations of environmental institutions led to the loss of qualified personnel, documentation and archives, and made it impossible to obtain reliable information about the state of natural components. This threatened the existence of rare vegetation. In addition, the complete absence of anthropogenic impact (in mined areas) is also negative for rare steppe communities because the steppes are rapidly overgrown with shrubs in such cases.

The most large-scale impact is noted for the fires that in 2014 alone engulfed, according to Lisova (2017), more than 297 thousand hectares, including more than 110.215 hectares of steppes, or 23.7% of the area of steppes within the military conflict zone. Such an extraordinary increase in the number of fires in eastern Ukraine is a direct consequence of military aggression against Ukraine. The following factors contribute to the increase in the number and scale of fires: the dry season, the inability to extinguish fires, explosions, deliberate arson, spilled fuel oil in the forest and forest belts, and their fire-raising to create smoke clouds. Fire has also damaged a number of NRF objects: the Department of Nature Reserves “Provalsky Steppe”, “Trekhibzensky Steppe”, Regional Landscape Parks “Donetsk Ridge” and NNP “Sviati Hory”, and numerous steppe reserves.

Review of publications on the nature of militarization and the impact of military operations, as well as an analysis of measures to improve the state of plant communities (Quist et al., 2003; Leis et al., 2005; Yager et al., 2005; Jentsch et al., 2009; Julien et al., 2022) showed that an extremely important and appropriate task is to map and zone reference objects affected by armed aggression, and the allocation of different zones in their composition by type and degree of pollution. Such mapping and zoning after the preservation of the reserve status on the reference territory will allow assessment of its overall state and the state of its individual elements. Their constant monitoring will allow us not only to assess the loss of biodiversity but also to prevent ploughing, building on, or other forms of spontaneous exploitation of this territory.

Studying the processes of vegetation cover restoration under the above conditions can give scientific results valuable in a botanical sense. Biosphere reserves, nature reserves, and national nature parks that represent landscape complexes with appropriate floral, phytocenotic, and faunal components typical or exceptional for a particular natural zone should also become reference territories for cartographic monitoring works. The results of comprehensive research within these institutions were already reflected in numerous scientific publications, as well as in the annual reports of these institutions (annals of nature). The use of this information in conjunction with international and state standards for soil, surface, and groundwater quality is urgently required for remote sensing mapping of affected areas. Remote sensing is the first stage of creating maps that provide general information about the studied areas even prior to their survey and clearing of explosive objects in the de-occupied territories. The second stage after demining is comprehensive field research which aims to clarify information obtained remotely.

Given the significant disturbance of the vegetation cover integrity and the emergence of free ecological niches suitable for the invasion of new alien species in territories affected by military aggression, accounting for such alien species is extremely important. Invasive species take up a significant share of such species. They can successfully compete with native species, leading to a decrease in the number and even to the extinction of the latter and, as a result, to the loss of biodiversity. Some of them are even dangerous to human life and health.

After the end of military operations, it will be very important to study the features of the spread of such alien species, their biology, population characteristics, consort, allelopathic and other relationships with native

species and develop measures to eliminate or reduce their number. In this case, reference sites should be both the territories of nature reserves and various anthropogenic territories (junction railway stations, main roads, etc.), where the number and diversity of alien species will be higher than in native phytocenoses.

The active destruction of the steppe territory covered with native vegetation by economic activity significantly increased with agricultural intensification (in the pre-war period) and the creation of a land market. This is facilitated by the poverty of the population, the use of outdated agricultural production technologies, imperfect environmental regulation, insufficient information on the status of species and plant communities, inadequate management of protected areas, uncoordinated environmental measures, ineffective sanctions, and insufficient monitoring. The reasons for this are restrictions on funding for environmental protection measures, non-compliance with environmental standards, and impunity for legal entities and individuals. There is unauthorized ploughing of virgin land plots, irrational afforestation on steppe slopes, and, as a result, the destruction of the last remnant steppe plant communities, including those listed in the Green Book which require priority protection.

Minimizing these unfavourable processes requires improving environmental and land legislation, taking ecosystem services into account when conducting cadastral works and economic assessments of land, and strengthening the environmental literacy of the population. Restoration of disturbed areas of natural steppes in the post-war period requires strengthening the responsibility of the population and heads of relevant organizations, and compliance with environmental legislation.

At the end of the 20th – beginning of the 21st century, the threat of critical disturbance of the steppe territory was not yet relevant and did not have the characteristics of an irreversible trend. Ten years later it had increased significantly. The modern method of agricultural technology is the spread of monocropping over large areas of plantings; its high biological productivity is achieved due to artificial fertilizers and pesticides, and it threatens irreversible impoverishment of biodiversity at the regional and local levels. Toxic substances enter natural areas and forest belts bordering fields. Herbicides sometimes destroy natural vegetation and protective forest belts at a distance of up to 100 m from field borders.

The greatest difficulty in solving the problem of saving the steppes is the land issue. Ukrainian land legislation is imperfect in the environmental aspect and requires certain changes. In the mid-1990s, programs for land conservation (i. e. reproduction of native vegetation) were developed for an area of more than 9 million hectares of eroded arable land. Unfortunately, the programs did not work, because, at the same time, the state began the process of the division of individual land shares aimed at the privatization of agricultural land, primarily arable plots. More than 275 thousand km<sup>2</sup> of farmland or 45.5% of the country's territory was divided (Burkovsky et al., 2013). In particular, significant areas of eroded arable land and pastures were ploughed up. Now it is almost impossible to legally force the owner of a land share not to use it as arable land, but to transfer it to a natural or semi-natural state. In addition, the legislation defines a clear purpose of cleared land as conducting commercial agricultural production. The owner of a land share does not have the right to use it in any other way. This means that the shortage of natural ecosystems, a high percentage of arable land, and therefore mass soil erosion, are fixed in Ukraine by law. Conservation of owned land can be considered as inappropriate use of it.

Today in Ukraine, the issue of developing the land market is acute. Unfortunately, when evaluating the land, the latter is considered mainly as a natural resource and means of production in agriculture and forestry. In this respect, only economic indicators are used that characterize land productivity, efficiency of use, and profitability per unit area in monetary terms. But so far, our legislation has not applied an ecosystem approach that would take into account the anti-erosion, recreational, sanitary-hygienic, and biocenotic significance of certain lands (Didukh & Vakarenko, 2019). The definition of the term "agricultural land" is rather unspecific, blurry, and already a subject of discussion. After all, these lands include not only arable land, but also hayfields, pastures, and forests, which can be of great environmental importance. At the same time, a situation arose when, on the one side, the authorities do not have information about the value of land, do not have an assessment of its ecological significance,

and, on the other side, the laws of land use are not spelled out in favour of their protection or preservation. Even today, acute conflicts arise between the need to preserve and the need to use natural resources. In the future, these conflicts will escalate upon obtaining land sales permits.

The creation of a substantial number of quarries in steppe areas resulted in destroying their native vegetation and irreversibly changed the landscape. The latter significantly complicates natural recovery processes and sometimes makes them impossible. In addition, rock dumps serve as places of concentration of invasive alien species, including many transformer species that can invade native plant communities, including rare ones, and change them (such species as *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Elaeagnus angustifolia* L., *Grindelia squarrosa* (Pursh), etc.). Factors that encourage the local population to engage in illegal coal mining are the growth of actual unemployment, difficulties in obtaining fuel in conditions of turning off the central heating, etc. Illegal chalk extraction by quarry method is observed in the Kharkiv, Donetsk, and Luhansk regions, sometimes even in the territories of nature reserves ("Kolodezyansko", "Korobochkino" reserves within Kharkiv region). As a result of such actions, unique plant communities growing exclusively on chalk outcrops (communities of formations *Artemisieta hololeucaea*, *Hedysareta cretacei*, *Helianthemeta cani*, *Hyssopeta cretacei*) are destroyed.

In recent decades, jeeping (rally raids), or off-road racing on all-terrain vehicles in natural areas has become quite popular. Threats from such activities to the environment are related to the following facts:

- vehicles destroy plants and animals with their wheels, as well as the topsoil;
- vehicles create deep ruts or unpaved roads with compacted soil, which provoke erosion processes, especially in sloping areas;
- a significant number of vehicles and people stay at the same time on the territory, which significantly increases the unfavourable impact on the environment;
- in steppe territories, vehicles move in different directions and destroy the microrelief.

Especially attractive for the organizers of such races are territories characterized by complex terrain, or open spaces. Officially, jeeping on NRF territories is prohibited by the law of Ukraine "On the nature reserve fund of Ukraine", but this prohibition is often ignored. The fact of conducting rally raids was revealed on the territory of NNPs "Oleshky Sands", Kinburn Spit, NNP "Dvurichansky", which affected the vegetation of sandy steppes on the coast of the Kuyalnik Estuary (Dubyna et al., 2019b).

At the moment, there are known negative examples of illegal economic use of protected land in the territories of the steppe zone of Ukraine covered with the most valuable chernozem soils. So, in November 2016, more than 900 hectares of the territory of the Nature Reserve "Tarutinsky Steppe" were ploughed up. Losses caused by the destruction of plant species listed in the Red Book amounted to 4,404,748,800 UAH for the plowed territory of the Reserve. And the cost of ecosystem services of this site at the lowest threshold was UAH 7,728,000 (Popova et al., 2017).

The biggest drawback of official documents in Ukraine in regard to the challenge of large-scale land degradation is ignoring the decree on ecosystem functioning. Hence, the unreasonable afforestation of steppes directly violates the laws of Ukraine "On the Nature Reserve Fund of Ukraine", "On the Plant Kingdom", "On the Ecological Network of Ukraine", etc., as well as international environmental conventions ratified by Ukraine.

Deliberate destruction of the remnants of steppe ecosystems began, unfortunately, in regards to the Decree of the President of Ukraine No. 995/2008 of 04.11.2008 "On some measures for conservation and restoration of forests and plantations". According to this document, new indicators of the area under forest (20%) should be established and approved in Ukraine to create new forests on reserve, degraded and unproductive lands. The regional authorities had to identify these "degraded, unproductive and other lands" that it was advisable to allocate for afforestation. Often this concept included the last remnants of steppe vegetation growing on the ravine slopes and not really degraded agricultural land that needs to be excluded from cultivation.

On November 21, 2017, the President signed a new Decree No. 381/2017 "On Additional Measures for the Development of Forestry, Rational Use of Nature and Preservation of Objects of the Nature Reserve

Fund". However, the analysis of this document called into question its professionalism, expediency, and the possibility of its practical implementation. Some items may, on the contrary, cause harm to the environment. The decree stipulates the approval of the program "Forests of Ukraine-2030" and stepping-up work on forest reproduction, including increasing their area, afforestation of land not suitable for economic use, coastal strips of water bodies, creating economic incentives for expanded forest reproduction and improving the efficiency of forestry activities.

This is an extremely dangerous point for steppe plant communities since the program "Forests of Ukraine" provides for increasing the forest area through artificial afforestation. It is in accordance with regional forest standards in the regions of the steppe zone on natural steppe areas situated in ravines and on slopes. Such plans directly threaten with complete destruction of animals and plants listed in the Red Book of Ukraine (RBU) and plant communities listed in the Green Book of Ukraine.

In Ukrainian legislation, the concept of "Steppe" has no definition. There is no targeted legislative act that would protect the steppe or regulate its use. Areas that do not belong to the nature reserve fund, but which are inhabited by steppe species of flora and fauna, are usually designated in official documents as pastures and badlands. Thus, if there is no legal term "steppe", then it is deprived of protection at the state level. The land reform left in state ownership a few lands of the steppe zone, represented by badlands, which actually are steppes. They are exactly under threat of destruction. No one has any doubts about the need to restore the system of forest belts in the steppe part of Ukraine. But the paradox of the situation is that the land is already subdivided and it is illegal to plant forest belts on it at public expense. The same forest belts that already exist are usually located outside the forest fund, so the state forestry agency cannot spend budget funds on their reconstruction.

In addition, it is obvious that the creation of artificial forest stands in the steppe zone of Ukraine is problematic in the current climatic conditions. 80% of newly created plantings burn from steppe fires in the first two years or simply dry up in conditions of lack of moisture and soil salinity. This is evidenced by significant areas of degraded or completely dried or burnt artificial tree and shrubby stands on the terraced slopes of ravines (Dubyna et al., 2019b). In areas where forest stands have not taken root, ruderal plant communities are developed, which include many adventive species, including transformer species. Native steppe communities, especially rare ones, are not restored in such areas. Afforestation is often carried out with alien tree species, such as *Robinia pseudoacacia* L., *Fraxinus lanceolata* Borkh., *F. americana* L., *Elaeagnus angustifolia* L., *E. commutata* Bernh. ex Rydb., etc.). Invasive plant species independently actively spread through steppes, saline soil, and sands and radically transform native communities.

Since many NRF objects in Ukraine have not yet been mapped with geodetic survey data, there is a high probability of accidental assignment of their territories for afforestation, since they are not included in the state land cadaster. For example, the afforestation of the "Chingul River Floodplain" Steppe Reserve, the richest in rare fauna and flora, and other virgin steppe areas in the Tokmak district of the Zaporizhia region became popular. After the state enterprise "Primorskoe Forestry" was forced to stop working, plots in the neighbouring Reserve "Troitskaya Balka" in the Melitopol district were afforested. Due to illegal afforestation in 2009, Ukraine has lost a unique territory reserved for the expansion of the Elanetsky Steppe Nature Reserve in Mykolaiv region (Burkovsky et al., 2013). In fact, potential areas for creating new forest plantations are eroded arable land, degraded forest belts, and mine dumps, where forests recover very slowly.

One of the paradoxical examples of the use of steppe landscapes is alternative or "green" energy. At first sight, it should improve the ecological situation, but it becomes a new factor that destroys the native vegetation of steppe areas due to imperfect land legislation. "Green" power plants require large areas. For example, a 1,000 MW wind farm can take anywhere from 70 to 200 km<sup>2</sup> (Burkovskyi et al., 2013). The installation of wind turbines in any natural area means that their operation, maintenance, and provision of communications turns this territory into an anthropogenic state. Similar threats are posed by solar energy facilities. Today in Ukraine, it is easiest to place "green" power plants on the latest native landscapes that do not have conservation status. When allocating land,

local authorities do not take into account the presence of species listed in the RBU or in communities of the GBU and steppe ecosystems protected by the Bern Convention.

A recently increased threat is also the expansion of adventive species and their replacement of typical zonal and rare species in steppe communities. Currently, 706 adventive plant species are registered within the steppe zone of Ukraine. Of these, 374 species grow in steppe biotopes. The threat exists with the development of civilization, but its level of influence has increased in recent decades due to global warming and military operations. Adventive species are actively spread in various ways (by road, rail, etc.), and some of them acquire the status of invasive and transformer species.

Recently, the spread of adventive and invasive species has become an increasingly significant environmental threat (Pergl et al., 2016; Wagner et al., 2017; Moodley et al., 2020; Rai & Singh, 2020). Anthropogenic and climatic changes activate the invasion of new adventive species and increase the invasiveness of existing ones (Fahey et al., 2018). This is a threat to the conservation of biodiversity of plant communities, especially rare ones (Paal, 1998; Alexander et al., 2016; Crisfield et al., 2020; Shackleton et al., 2020).

The adventization of native steppe communities is also increasing due to global warming and military operations. Invasive species pose a threat to plant communities that are crucial for biodiversity conservation and to their functional and phylogenetic changes. Therefore, measures are needed to assess adventization by various criteria, control of alien species and risks of transformation of rare communities (Baider & Florens, 2011; Izco, 2015; Fanfarillo et al., 2020).

Control and restriction of adventization of steppe communities require further improvement of environmental and land legislation, and the development of regional lists of adventive and invasive species with recommendations for limiting their expansion.

The complex of negative actions of these threats for more than ten years has led to significant losses of the phytocenofond of the steppe zone in Ukraine. From the total phytocenofond of the region (1912 associations, 239 formations) (Didukh, 2009) the rare phytocenofond consisted of 271 associations, which included 126 rare associations (46.5%, Fig. 3).

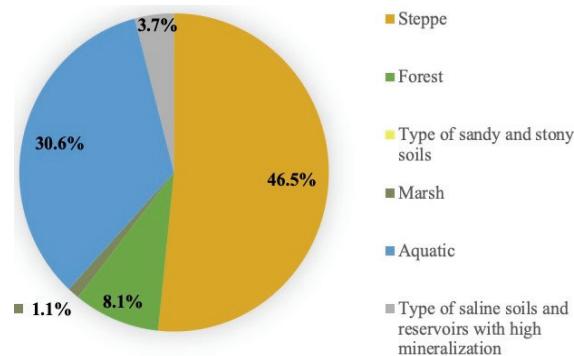


Fig. 3. Share of rare steppe communities in the composition of rare phytocenodiversity according to the "Green Book of Ukraine" (2009)

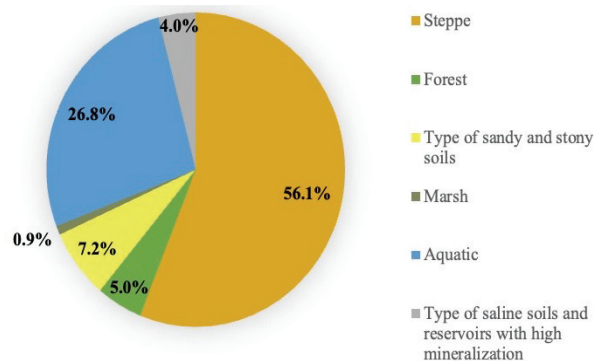


Fig. 4. Share of rare steppe communities in the composition of rare phytocenodiversity for the current period

Currently the rare phytocenofond includes 321 associations, and steppe vegetation accounts for 180 rare associations (56.1%, Fig. 4). This indicates the transition of a number of plant communities from ordinary to rare. On the one hand, steppe territories that do not have a nature protection status are not protected from active economic use. On the other hand, according to the law “On the Red Book of Ukraine”, the provisions “On the Green Book of Ukraine”, the Berne Convention, and other legal documents concerning the protection of nature, the habitats of rare and endangered species and their habitats should not be destroyed.

## Conclusion

Global warming in Eastern Europe leads to significant changes in the functioning of natural steppe ecosystems and, primarily, their plant unit. These changes are due to fires, xerophytization, salinization, ruderalization, and adventization. It also has two consequences for vegetation cover: an increase in average annual and spring-summer temperatures, as well as an increase in precipitation. This, on the one hand, contributes to better plant viability, and on the other – to the spread of many adventive species of southern ranges as part of steppe rare cenoses.

Unfavourable, and more often catastrophic impact on steppe ecosystems is caused by a complex of military factors: arson leading to large-scale fires, explosions of shells and mines, construction of trenches and other fortifications, physical and chemical pollution. An extremely important and expedient task, which should be carried out in conjunction with the study of the vegetation cover dynamics, is the mapping and zoning of reference objects affected by armed aggression, with the allocation of different zones in their composition according to the type and level of pollution.

Active disturbance of the territory of steppes covered with native vegetation by economic activity significantly increased with agricultural intensification (in the pre-war period), the creation of a land market, the use of outdated agricultural production technologies, unauthorized ploughing of virgin land, etc. Disturbance of natural steppe communities including those listed in the GBU requires priority protection.

A recently increased threat is the expansion of adventive, invasive, and transformer species and their replacement of typical zonal and rare species of steppe communities. The level of its impact has increased in recent decades due to global warming and military operations. Adventive species actively spread in various ways, and some of them acquire the status of invasive species, and especially transformer species. Their expansion requires monitoring, further improvement of environmental legislation, and the creation of regional lists of adventive and invasive species with recommendations for their restriction.

The influence of a complex of unfavourable factors has already led to a significant expansion of the list of rare steppe communities in comparison with the communities of other types of vegetation.

The preservation of rare grass, shrubby and subshrubby communities in the steppe zone of Ukraine should be provided with proper support at the state level. The basics and mechanisms for the implementation of the law of Ukraine “On the preservation of the steppes in Ukraine” need to be further developed. The issue of developing a strategy for the conservation and balanced use of steppe ecosystems in Ukraine has long been raised, which should be implemented in an integral system of long-term and operational goals for the environmental, economic, and social development of the regions. The main goal of the strategy would be the real conservation of steppe communities, most of which are currently rare, ensuring minimization of their degradation and instead ensuring their restoration, stopping the loss of biodiversity, and promoting balanced use of natural resources.

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