Biol. Stud. 2025, 19(3), 211–234 • doi: https://doi.org/10.30970/sbi.1903.847
www.http://publications.lnu.edu.ua/journals/index.php/biology

UDC: 581.526.3(477:243.7.05)

SUCCESSIVE ANTHROPOGENIC CHANGES OF THE VEGETATION IN THE KILYAN ARM OF THE DANUBE DELTA (UKRAINE)

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Borsukevych, L., Dubyna, D., & Dziuba, T. (2025). Successive anthropogenic changes of the vegetation in the Kilyan arm of the Danube Delta (Ukraine). *Studia Biologica*, 19(3), 211–234. doi:10.30970/sbi.1903.847

Background. In the past, floodplain vegetation, typical of estuarine ecosystems affected by a moderate surge wind phenomenon, prevailed in the Kilyan arm of the Danube Delta (Ukraine). The vegetation of this territory was represented mainly by meadows, swamps, and wetlands. Forest vegetation occupied only small areas. At the beginning of the previous century, natural complexes of the Kilyan arm of the Danube Delta underwent significant anthropogenic transformations. We distinguish two types of anthropogenic factors – large-scale and local – the latter referred to as successive. While anthropogenic, especially large-scale, pressure on natural ecosystems of the delta leads to a catastrophic alteration of the ecological regime and degradation of native flora complexes and plant communities, successive changes lead mostly to a decreased species diversity, biological productivity, and degradation of biocenoses. The main factors of local anthropogenic transformation of ecosystems are grazing-induced vegetation changes, mowing-induced vegetation changes (harvesting of reed and hay cutting), pyrogenic, biochemical changes, and afforestation. With their long-term influence and heavy load on biotopes, successive changes turn into catastrophic. On the contrary, when their influence is insignificant, or removed, the original native vegetation is restored.

Materials and Methods. Long-term comparative phytocoenotic surveys and semi-stationary studies were used in this research. The studies of the anthropogenic dynamics of vegetation were carried out by direct methods – on semi-stationary sites, as well as by indirect methods. The direct methods included comparing the current data with historical maps and geobotanical descriptions presented in the monograph «Reserve “Wetlands of the Danube”». Indirect methods included the reconstruction of successive trends based on the analysis of ecological and coenotic profiles.

Results and Discussion. The syntaxonomic structure of vegetation in the delta is analyzed. The paper highlights the main local successive anthropogenic changes of vegetation identified based on long-term comparative phytocoenotic surveys and semi-stationary studies. The anthropic changes in vegetation occur under the influence of powerful external factors associated with human activity. In the delta area, the anthropic changes exceed natural in terms of their scale and degree of influence. The main factors of such changes are grazing-induced and mowing-induced vegetation changes, pyrogenic, biochemical changes, afforestation etc. The halophytic and halophytic meadow vegetation of the coastal areas is most affected by the pasture. The sandy steppe and shrub vegetation are influenced by pyrogenic factor and forest logging. The influence of the mowing-induced factor is manifested on a narrower scale. The pressure of local anthropic factors are enhanced by the influence of global or local natural factors. The complex effect of local anthropogenic and global climatic factors on communities leads to their unification, loss of the autochthonous elements, and formation of unproductive associations. The most endangered are steppe and psammophyte vegetation with representatives of the psammophilous-littoral neoendemic pontic floristic complex.

Conclusion. The strategy for optimizing the vegetation cover of the Kilyan arm of the Danube delta is offered. Preservation, restoration, and maintenance of the delta vegetation in the conditions of regulated river flow and climate change can be achieved through the extraction of a certain volume of plant material by mowing, grazing, and winter burning of grass. These measures should be preceded by an assessment of negative changes and their trends, as well as careful control over their implementation. A moderate pasture and mowing loading contributes to the increase of the species composition and communities’ productivity and the preservation of rare species.

Keywords: local changes, dynamic, plant communities, Kilyan arm, Danube Delta, Ukraine

INTRODUCTION

The dynamism of alluvial processes is the main feature of delta biotopes. Specific plant communities are formed here. Their peculiarities are determined by species composition and structure, which develop as an adaptation to the impact of ecological changes and species-forming processes (Dubyna *et al*., 2003). The Danube Delta is characterized by a high diversity of ecosystems. The presence of large areas of swamp vegetation helps maintain the hydrological regime and purify water. The aquatic areas of the delta are the habitat for commercial and rare fish species. Wetland biotopes are nesting, molting, and wintering places for many bird species. They are an integral part of the Afro-Eurasian migration route of waterfowl. Wetlands absorb and store large amounts of carbon and help mitigate the effects of climate change. However, they are very vulnerable and sensitive to anthropogenic influences (Syvitski & Saito, 2007; Loucks, 2019).

Changes that are local in nature (geitogenetic) are characteristic of the studied region. They occur under the influence of external factors unrelated to the general trends of landscape development. As a rule, these factors are of anthropogenic origin and can affect vegetation, both accidentally and indirectly, due to the impact on the environment.

The study of dynamic trends in the Danube Delta also becomes important due to global climate changes and relative sea level rise (Bianchi & Allison, 2009; Cozzi *et al*., 2019). According to the calculations and modeling of the rise in the level of the Black Sea, the projected flood zone for the year 2100 will completely cover the Danube Delta. Almost 100 % of the Danube Biosphere Reserve landscapes will be flooded by the sea. Other landscapes are also affected: a change in their salinity and temperature regime can lead to disruption or degradation of ecosystems (Golubtsov *et al*., 2018).

The formation and functioning of the vegetation of the anthropically altered territories of delta regions attracted the attention of many researchers (Tkachenko, 1984; Dubyna & Shelyag-Sosonko, 1989; Syvitski *et al*., 2009; You *et al*., 2015). In the Danube Delta, which is located on the territory of two countries, Romania and Ukraine, vegetation dynamics has been studied by Ukrainian (Dubyna & Shelyag-Sosonko, 1989; Klokov & Diachenko, 1993; Diachenko, 2010) and Romanian (Godeanu, 1976; Oosterberg & Staraş, 2000; Anastasiu *et al*., 2011; Doroftei *et al*., 2011; Strat, 2013; Schneider-Binder, 2018; Trifanov *et al*., 2018) scientists. T. Dvoretskyi (Dvoretskyi, 1999, 2002, 2004) studied the effect of mowing on the swamp and meadow vegetation of the Ukrainian part of the delta, O. Zhmud (Zhmud, 1999) documented natural and anthropogenic changes in the vegetation of the Danube Biosphere Reserve. Recommendations for the sustainable use of plant resources in the Danube Delta under the protected regime were prepared by D. Dubyna (Dubyna *et al*., 2003).

This work aims to determine the features of anthropogenic changes in the vegetation cover of the Kilyan arm of the Danube Delta in order to provide solutions to problems of biodiversity conservation.

The Danube Delta begins to the southwest of the city of Izmail, at the place where the Danube River divides into two branches near Cape Izmailsky Chatal, 80 km from the mouth: the Kilyan estuary and the Tulchynsky estuary. The Tulchynsky arm, 17 km downstream, branches into the Georgiev and Sulina estuaries, which flow into the Black Sea separately and are located on the territory of Romania. The Kilyan arm, which is the most flooded, is located on the territory of Ukraine and flows into the Black Sea southeast of the town of Vylkovo (**Fig. 1**).

The border between Ukraine and Romania runs along it. The length of the arm is 116 km, the width is up to 1.2 km. The area of the Kilyan arm of the Danube Delta is 1200 km² and is constantly increasing due to alluvial deposits. The lower part of the estuary is located within the Danube Biosphere Reserve with an area of 50252.9 ha. It is a part of the bilateral Romanian-Ukrainian Danube Delta Biosphere Reserve, one of the five bilateral reserves in the world. The Danube Biosphere Reserve is included in the UNESCO World Network of Biosphere Reserves. The wetlands of the Kilyan arm of the Danube Delta were included in the List of Wetlands of International Importance under the Ramsar Convention in 1995.

According to the geomorphological zoning, the Kilyan arm of the Danube Delta is placed within the boundaries of the Lower Danube Delta and alluvial (terrace) flat-lowland subregion of the Black Sea region (National Atlas of Ukraine, 2007). According to the geomorphological structure, it is a lowland flat alluvial and alluvial-estuarine plain, slightly dissected by gullies. The height of the delta above sea level in Izmail is 3.7 m, near the Sulina estuary – 0.5 m. About 87 % of the delta area is occupied by floodplains with a depth of 1–2, less often 3–4 m. The delta is swampy, covered by a dense network of inlets and lakes. On the territory of the delta, alluvial, meadow and meadow-swamp, swamp, sod-glazed soils and salt marshes are common (Izmail district, 2011).

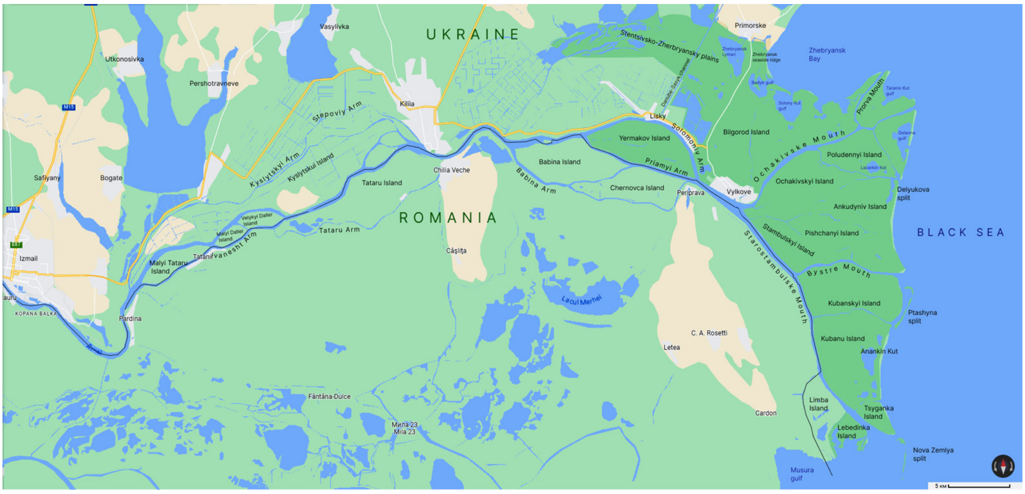

Fig. 1. Map of the studied territory

The surface of the territory is almost horizontal with a slight rise in the northern part. The highest are the coastal and riverbed-side areas, as well as the ridges of the Zhebryansk seaside ridge (up to 5–10 m). Positive elements of the relief are also sea spits and islands. They are formed in the sea at a certain distance from the islands of the Kilyan arm of the Danube Delta from sand and shell material. There are also artificial elevations in the delta – dams, ramparts, and alluvial (as a result of the deepening of watercourses) islands. Plain areas are divided into short-, medium-, and long-flooded areas according to the duration of the flood regime. In addition, the hydrographic network of the delta consists of numerous large and small watercourses, artificial canals, and reservoirs.

The climate of the Danube Delta is moderately continental with hot, dry summers and mild, unstable winters with little snow. The average monthly temperature in July is 22.5–23.0 °C, and in January – 2.0 °C. The duration of the growing season is 180–210 days. Average annual precipitation is 350–400 mm with an average annual evaporation of 800–900 mm. The water level in the Danube-Black Sea Canal and reservoirs depends on seasonal phenomena, the main of which is the flood that occurs in March–April. It has less influence on small rivers, lakes, and estuaries and does not occur in years with little snow. The water level is also affected by seawater surges and surges caused by winds.

MATERIALS AND METHODS

The dataset. The studies were carried out during 1973–2023 in the Kilyan arm of the Danube Delta. The objects of the research were plant communities of the Kilyan Danube Delta of all types of organization, identified in the course of preliminary reconnaissance work over the past two decades. In total, more than 1900 relevés were carried out by the authors during the field research. Plot areas range in size from 4–9 m^2 to 200 m^2 (25 m^2 on average), depending on the type of vegetation. Relevés were sampled using the Braun–Blanquet approach with the seven-grade scale of abundance and dominance of species (Braun-Blanquet, 1964).

Analysis. Long-term comparative phytocoenotic surveys, stationary studies, and the use of the successional series method were used in this research. The studies of the anthropogenic dynamics of vegetation were carried out by direct methods – on stationary and semi-stationary sites, as well as by indirect methods.

In order to clarify the mechanism of grazing-induced factors fences were used to create control conditions on stationary sites, and the number of cattle was recorded. We also used data about the wildlife which was collected by the staff of the nature reserve "Wetlands of the Danube" from the moment of its creation. In order to obtain quantitative indicators of the anthropogenic transformation of the vegetation cover, the stages of digression were distinguished according to the changes in phytomass and floristic composition. The first group of degradation (conditionally undisturbed communities) includes communities whose herbage differs from the control in terms of phytomass by less than 20 %, the second – from 20 to 40 %, the third – from 40 to 60 %, the fourth – from 60 to 80 % and more. Floristic composition varies, respectively: the first – from 1 to 10 %, the second – from 10 to 20 %, the third – from 20 to 30 %, and the fourth – more than 30 %. These indicators were obtained by the authors experimentally, but they can be used for rating similar geosystems.

The study of the influence of the mowing-induced factor was carried out on experimental plots in a threefold repetition. Three-time (July, September, November), two-time (September, November), and one-time (November) mowing of the grass was carried out.

The influence of the spontaneous pyrogenic factor was studied in the areas of natural fires in the secondary delta of the Kilyan arm and the Stentsivsko-Zhebryansky floodplain, as well as in the area of experimental mid-winter burning carried out by the staff of the Danube Biosphere Reserve (February 1999) in the Zhebryansky section of the Stentsivsko-Zhebryansky floodplain. The influence of summer fires on vegetation cover was also studied in other parts of the Kilyan arm of the Danube Delta, where every year in winter and summer, in order to improve pastures, the local population carried out spontaneous vegetation reduction. Areas that were untouched by fire were selected as control.

The direct methods included the method of comparing the current data with historical maps and geobotanical descriptions presented in the monograph «Reserve "Wetlands of the Danube"» (Shelyag-Sosonko & Dubyna, 1984). Indirect methods included the reconstruction of successive trends based on the analysis of ecological and coenotic profiles.

Nomenclature. Names of the species are given according to the "Nomenclatural Checklist of the Vascular Plants of Ukraine" (Mosyakin & Fedoronchuk, 1999), syntaxon names correspond to those given in the "Prodrome of the Vegetation of Ukraine" (Dubyna *et al*., 2019).

RESULTS AND DISCUSSION

Syntaxonomic structure of vegetation. The syntaxonomic structure of vegetation is represented by 205 associations belonging to 46 alliances, 36 orders, and 22 classes (Dubyna *et al*., 2003).

The vegetation of the *Lemnetea* and *Potametea* classes is the most typical for water bodies of the Danube Delta. This vegetation develops in conditions of fluctuating water levels during the growing season caused by the hydrological features of the Danube.

These communities are widespread mainly in low-lying plain areas (the secondary delta of the Kilyan arm of the Danube Delta and Stentsivsko-Zhebryansky floodplain) that are subject to medium- and long-lasting flooding. They include many rare and endangered communities listed in the Green Data Book of Ukraine (Didukh, 2009b). In particular, *Aldrovandetum vesiculosae*, *Trapetum natantis*, *Batrachietum rionii*, *Nymphaeo albae-Nupharetum luteae*, *Schoenoplectetum litoralis*, *Ceratophylletum tanaitici*, *Ceratophylletum submersi*, *Potameto natantis-Nupharetum luteae*, *Nymphoidetum peltatae*, *Potametum sarmatici*, *Lemnetum gibbae*, *Lemno-Salvinietum natantis*, *Butomo-Sagittarietum sagittifoliae.*

The distribution of aquatic vegetation is directly dependent on the degree of water mineralization. Coenoses of submerged vegetation cover shallow waters of the delta, as well as desalinated areas of the coast along the large channels – Ochakivskyi, Bystry, and Starostambulsky. Its distribution is uneven. In gulfs that are desalinated and isolated from the sea (Delyukiv, Anankyn corners, etc.), large areas of *Nymphaeo albae-Nupharetum luteae* coenoses are concentrated. New lakes in the stage of formation (Bystry and Velyky) are overgrown with coenoses of *Potametum pectinati* and *Nymphoidetum peltatae*. Phytocoenoses of brackish water bodies are typical for shallow waters of the northeastern parts of the coast. In the gulfs opening into the sea (Badyk, Solony, Durny and Taraniv) and in reservoirs with a slight influx of fresh Danube water, associations *Najadetum marinae*, *Potametum pectinati*, *Potameto-Zannichellietum pedicellatae*, *Zosteretum noltii*, *Zosteretum marinae* are represented. In reservoirs, where water mineralization decreases, coenoses of *Ceratophylletum demersi*, *Myriophylletum spicati*, *Myriophylletum verticillati*, *Potametum pectinati*, *Najadetum marinae*, and *Elodeetum canadensis* are most common. They usually form large thickets with an area of up to 10 ha.

The *Phragmito-Magnocaricetea* class is representative of the large-grass and large-sedge bogs of southern Europe. At the same time, functioning in arid conditions, it is distinguished by the specificity of its coenoses. The vegetation of the class in the secondary delta of the Kilyan arm of the Danube Delta is distinguished by a greater proportion of *Caricetum acutiformis*, *Caricetum pseudocyperi*, and *Typhetum angustifoliae* associations. In the Stentsivsko-Zhebryansky floodplain, it is represented almost exclusively by *Phragmitetum australis* coenoses. Here the coenoses of *Cladietum marisci* occur. They are absent in the secondary delta and are rare and disappearing in Ukraine. Due to the desalination effect of the Danube watercourses and the washing regime, the communities are not widely distributed.

Coenoses of meadow vegetation occupy relatively small flat coastal and riparian areas, depressions of coastal marshes, and other marginal areas. They are not widely spread due to the washing regime of the delta and are represented by halophyte meadow vegetation, mesophylous meadows, marsh and steppe meadows. The leading factor in the territorial differentiation of meadows is the flooding regime and its duration. In addition to natural factors, the economic usage of the territory, mainly grazing, has a significant impact.

The total area of halophyte meadows in the Kilyan arm of the Danube Delta is more than 700 ha. Coenoses of halophyte meadow vegetation are represented by *Bolboschoenetea maritimi, Juncetea maritimi*, and *Festuco-Puccinellietea* classes. In particular, *Bolboschoenetum maritimi*, *Junco maritimi-Caricetum extensae*, *Scorzonero parviflorae-Juncetum gerardii*, *Plantagini cornuti-Juncetum gerardii*, *Junco gerardii-*

Triglochinetum maritimi, *Limonio gmelinii-Juncetum gerardii* associations. They are in the third position by the areas they occupy. Coenoses of marsh meadows (*Glycerietum maximae*, *Caricetum gracilis, Carici acutae-Glycerietum maximae*, *Agrostietum stoloniferae*, *Phalaridetum arundinaceae*) are typical of the still weakly transformed depressions of channel ridges and long-flooded plain areas of the secondary Danube Delta. Communities of steppe meadows (*Poëtum angustifoliae*, *Agropyretum repentis*, *Calamagrostietum epigei, Cynodonetum dactyloni*) occupy small areas and are confined to the terraced areas, depressions of the arenas of the Zhebryansk seaside ridge. Mesophylous meadows of the *Molinio-Arrhenatheretea* class (*Festucetum pratensis, Poëtum pratensis, Bromopsietum inermis*) are formed on short-flooded plain areas, riparian ridges, and depression arenas.

Saline vegetation (about 3 %) is widespread in the coastal zone and is concentrated mainly on flat areas that are short-flooded during the sea flood. Represented by coenoses of *Limonio meyeri-Artemisietum santonicae*, *Agropyretum elongatae*, *Caricetum distantis*, etc. Salty marshes are characteristic of the same geocomplexes as saline vegetation, but are confined to areas of excessive salinity and occupy less than 5% of the territory. They are located in depressions and are typical of islands with high pasture pressure and the absence of a washing regime. Its vegetation is represented by coenoses of the classes *Therosalicornietea* and *Kalidietea foliati,* mainly coenoses of *Salicornietum prostratae, Bassietum hirsutae*, *Halimionetum pedunculatae*, etc.

Coenoses of floodplain forests presented by *Salicetea purpureae* (*Salicetum albae*, *Salici-Populetum*) class occupy about 1% of the area. They are more characteristic of the islands and the secondary delta of the Kilyan arm of the Danube Delta. They are common on riverbed-side ridges of the main and secondary watercourses and sometimes occur on the plain areas of the floodplain. There are significant areas composed of *Salix alba*, *S.* x *rubens*, *Populus alba*, *P. nigra*, *P. deltoides*.

Shrub vegetation occupies approximately 1 % of the area and is represented by *Calamagrostio epigei-Hippophaëtum rhamnoidis*, *Tamaricetum ramosissimae*, *Elaeagnetum angustifoliae* (*Salicetea purpureae* class) associations and is common mainly on coastal spits. On the Zhebryansk seaside ridge, significant areas are occupied by the *Salici rosmarinifoliae-Holoschoenetum vulgaris* coenoses. The coenoses of *Salicetum triandrae*, *Salici acutifoliae-Amorphetum fruticosae*, and *Salicetum cinereae* are characteristic of the riparian ridges of the youngest southern part of the secondary Danube Delta.

Psammophytic vegetation is spread in the areas of the seaside spits and occupies about 1 % of the area. It is confined to the arenas of the Zhebryansk seaside ridge and the seaside spits of the secondary Danube Delta. It is represented by coenoses of *Cakiletea maritimae*, *Ammophiletea*, and *Festucetea vaginatae* class, in particular, *Elymetum gigantei*, *Artemisietum arenariae*, *Crambetum maritimae*, *Festucetum beckeri*, *Secalo-Stipetum borysthenicae, Centaureo odessanae-Festucetum beckeri, Dauco guttati-Chrysopogonetum grylli*, *Carici colchicae-Holoschoenetum vulgaris* associations. Most of them are rare in the region. They include rare species and neoendemics (*Apera maritima, Centaurea borysthenica, C. odessana*, *Chrysopogon gryllus*, *Dianthus bessarabicus*, *D. platyodon*, *Eremogone rigida*, *Senecio borysthenicus*, *Stipa borysthenica,* etc.) (Dubyna *et al*., 2003). The development of psammophytic vegetation occurs on geocomplexes of marine and river origin. The largest areas with this type of vegetation are concentrated in the Zhebryansk seaside ridge.

Synanthropic vegetation belongs to the *Artemisietea vulgaris, Stellarietea mediae, Bidentetea, Robinietea* class, in particular, *Agropyretum repentis*, *Artemisietum vulgaris*, *Ivaetum xanthiifoliae*, *Chenopodietum stricti*, *Polygonetum arenastri*, *Bidentetum tripartitae*, *Chelidonio-Robinietum* associations. It occurs on dams and anthropogenic landscapes along roads, in gardens, fields, recreation areas, etc. They are characterized by a gradual expansion of areas.

Unique delta ecosystems and their florocoenotic complexes are protected in the Danube Biosphere Reserve. A significant number of species that are found only in the Danube Delta are represented here: *Azolla caroliniana*, *A. filiculoides, Melilotus arenarius*, *Arenaria leptocladus*, *Cyperus difformis*, *Rumex halacsyi*, *Trapa danubialis*, *Chenopodium pumilio*, *Euphorbia maculata*, *Sagittaria latifolia,* etc. Some species are representatives of the ancient flora, in particular, *Cladium mariscus*, *Periploca graeca*, species of the genus *Trapa*, *Najas*. There are many boreal species that are not typical for the steppe zone (*Calamagrostis pseudophragmites*, *Equisetum hyemale*, *Polygonum mite, Hottonia palustris, Potamogeton compresus, Naumburgia thyrsiflora, Comarum palustre, Thelypteris palustris,* etc.). There are 16 species listed in the Red Data Book of Ukraine (Didukh, 2009a). In particular, *Trapa natans, Leucojum aestivum, Cladium mariscus, Orchis palustris, Epipactis palustris, E. helleborine, Dactylorhiza majalis, Aldrovanda vesiculosa, Chrysopogon gryllus, Stipa borysthenica, S. capillata, S. lessingiana, Nymphoides peltata, Salvinia natans, Astrodaucus littoralis, Dianthus bessarabicus. Aldrovanda vesiculosa, Nymphoides peltata, Trapa natans*, and *Salvinia natans* are listed in Appendix I of the Bern Convention.

The main factors that affect the formation of vegetation are hydrogenic and anthropogenic. Anthropogenic factors are currently the most significant in terms of their transforming influence on plant communities.

Successive anthropogenic changes of the vegetation. Successive anthropogenic changes of the vegetation cover in the Danube Delta include grazing-induced, mowing-induced, pyrogenic, biochemical, and afforestation. With their long-term influence and heavy load on biotopes, successive changes turn into catastrophic. On the contrary, when their influence is insignificant, or removed, the original native vegetation is restored.

Grazing-induced vegetation changes. Livestock grazing in floodplains throughout the year is a historically formed kind of nature management in the Danube Delta. Most common are horses and cattle of local breeds surviving the winter period in natural conditions. They are adapted to eat coarse fodder, presented by reeds, cattails, various species of sedges, and other types of marsh and meadow forbs.

Under the influence of livestock, meadow forbs are formed. They are territorially limited to floodplain ecosystems and can function only in conditions of moderate grazing. In this regard, in order to maintain a high level of biodiversity in delta ecosystems, grazing wild or domestic animals (cows and horses) is necessary. This is also evidenced by the positive experience in many countries around the world (Borer *et al*., 2014; Otfinowski & Coffey, 2022; Kulik *et al*., 2023).

Grazing-induced changes of floodplain forest vegetation with low grazing, which corresponds to the first stage of pasture digression, do not cause noticeable changes in the structure of coenoses (**Fig. 2**).

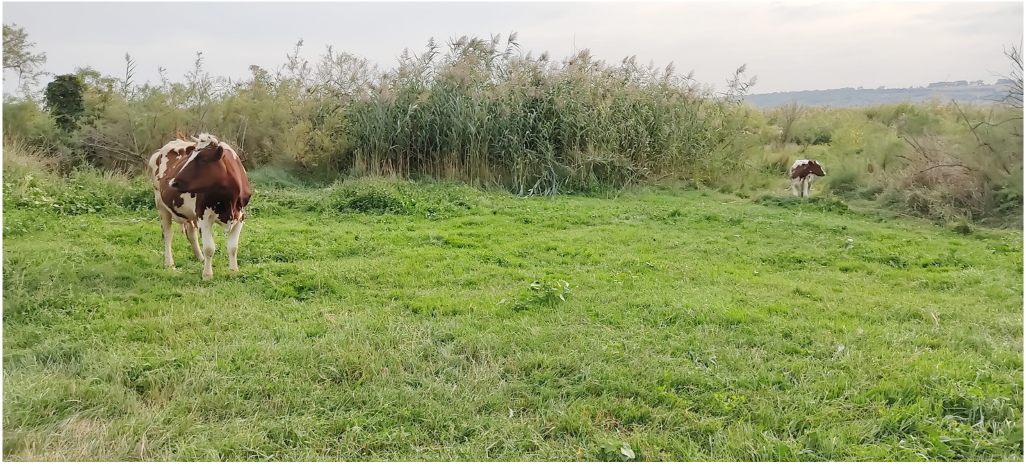

Fig. 2. Moderate cattle grazing in the Danube floodplain

Moderate pasture loading (2–3 up to 5 heads per 1 ha) is characterized by an increase in the species composition. With an increase of loading up to 5–10 heads per ha (stages II–III of digression), some floodplain forests, mainly belonging to the class *Salicetea purpureae*, gradually disappear, and species resistant to the pasture pressure develop. Especially annual explerents (diagnostic species of the classes *Stellarietea mediae, Plantaginetea majoris*) flourish in such conditions. The second and third stages of grazing-induced changes are characterized by the appearance of mesophilous ruderal species in the herb layer of floodplain forests. With a decrease in the washing regime, diagnostic species of *Bolboschoenetea maritimi* and *Festuco-Puccinellietea* classes (*Juncion gerardii, Salicornio-Puccinellion* alliances) appear. At the fourth stage of digression, these species are included in biogroups formed mainly by *Salix alba*.

Moderate grazing (2-3 heads of cattle per 1 ha) of forest communities in non-flooded areas contributes to an increase in the species richness of the herb layer. With an increase of pasture load, a rapid replacement of dominants in the herb layer by diagnostic species of the classes *Stellarietea mediae, Bidentetea, Artemisietea vulgaris* and *Plantaginetea majoris* occurs. At the fourth stage, adventive species (*Ambrosia artemisiifolia*, *Atriplex prostrata*, *Chenopodium polyspermum*, *Eupatorium cannabinum,* etc.) predominate in the herb layer.

Grazing-induced changes of shrub vegetation (*Calamagrostio-Tamaricetum*, *Tamaricetum ramosissimae, Calamagrostio epigei-Hippophaëtum rhamnoidis*, *Salici acutifoliae-Amorphetum fruticosae*) are most characteristic of the coastal areas of Kubanu and Kubansky islands, as well as the Zhebryansk seaside ridge. The first and second stages of grazing-induced digression of the shrub vegetation take place in the direction of replenishing the species composition of the herb layer. The psammophytic group of species belonging to the class *Festucetea vaginatae*, including a wide range of endemics (*Chondrilla graminea*, *Centaurea odessana*, *Tragopogon borysthenicus*, *Senecio borysthenicus*, *Corispermum ucrainicum*, *Medicago kotovii*, *Carex colchica*, etc.) appears. The third stage (more than 5 heads per ha) is characterized by the penetration of meadow species of a wide ecological amplitude (*Calamagrostis epigeios*, *Elytrigia repens*, *Melilotus albus*, *Cynodon dactylon*, *Digitaria sanguinalis,* etc.) in the abovementioned shrub communities. At the same time, the participation of endemic species sharply decreases. The fourth stage is characterized by the predominance in the herb layer of synanthropic species (*Euphorbia seguierana*, *Tragus racemosus*, *Crepis ramosissima*, *Aegilops cylindrica*, etc.), as well as adventive (*Xanthium rupicola*, *Bidens frondosa*, *Lappula squarrosa*, Asperugo *procumbens*). In more humid areas, such species as *Echinochloa crusgalli*, *Setaria viridis*, *Lactuca tatarica*, *Tripolium vulgare*, *Puccinellia gigantea*, *Agrostis maeotica*, *Suaeda prostrata*, *Acorellus pannonicus* appear. Thus, shrub communities are more resistant to grazing than forest coenoses.

Grazing-induced changes of meadow vegetation are typical for the near-river sections of Kubanu, Kubansky, Starostambulsky, Belgorodsky islands, a large area of Yermakov Island, the Zhebryansk seaside ridge, where livestock graze all year round, but with different intensity.

Grazing-induced changes of swamp-meadow vegetation (the coastal parts of Kubanu and Kubansky islands) take place mainly in the direction of the formation of saline-meadow phytocoenoses. At the first and second stages, the richness in species composition rises due to the appearance of mesophyte species with a wide ecological amplitude (*Equisetum ramosissimum*, *Galega officinalis*, *Symphytum officinale*, *Polygonum hydropiper,* etc.). At the third stage, they are replaced by species of saline meadows (*Festuca orientalis, Juncus gerardii*, *Lepidium latifolium*, *Carex extensa, C. distans*), and at the fourth stage – by *Bolboschoenus maritimus*, *Tripolium vulgare, Glaux maritima,* etc. At this stage, phytocoenoses of long-flooded meadow ecotopes are characterized by the predominance of diagnostic species of *Therosalicornietea* and *Salicornietea fruticosae* classes, while medium and short flooded habitats are dominated by species of the class *Festuco-Puccinellietea* (Zhmud, 1999).

Grazing-induced changes of saline-meadow vegetation (the Zhebryansk seaside ridge) take place in the direction of the formation of solonetz (first and second stages) and solonchak (third and fourth stages) vegetation. At the first two stages, an increase in the number of species with a wide ecological range is observed. At the third and fourth stages, the number of species decreases, and they are replaced by solonchak species (*Salicornia prostrata*, *Suaeda prostrata*, *Halimione pedunculata*, *Puccinellia distans*, *Artemisia santonica*, etc.).

Grazing-induced changes of meadow vegetation (the Zhebryansk seaside ridge, Yermakov Island) take place in the direction of sandy-steppe vegetation formation with the dominance of mesoxerophyte species of a wide ecological amplitude (*Calamagrostis epigeios*, *Cynodon dactylon*, etc.) and species resistant to grazing (*Euphorbia seguierana*, *Marrubium peregrinum, Nepeta cataria*, *Centaurea odessana*, *Grindelia squarrosa*, *Artemisia austriaca*, etc.). The first and second stages are characterized by an increase in the number of species of wide ecological amplitude, and the third – by an increase in halophytes (*Atriplex littoralis*, *Mentha pulegium*, *Lycopus exaltatus*, etc.). The fourth stage is characterized by the replacement of species of wide ecological amplitude with saline meadow species (*Agrostis maeotica*, *Apera maritima*, *Cynanchum acutum*, *Bassia sedoides*) and diagnostic species of the classes *Therosalicornietea* and *Salicornietea fruticosae*.

Grazing-induced changes of meadow-steppe vegetation (the Zhebryansk seaside ridge) lead to the prevalence of species resistant to grazing: *Marrubium peregrinum, Nepeta cataria, Onopordum acanthium, Ballota ruderalis, Cirsium alatum, Xanthium albinum,* etc. The first and second stages are characterized by the participation of diagnostic species from *Festuco-Puccinellietea* and *Festuco-Brometea* classes, the third and fourth – by a decrease in the total number of species with the dominance of those that are resistant to grazing.

Grazing-induced changes of psammophyte vegetation are typical of the Zhebryansk seaside ridge, where about 150 heads of cattle grazed throughout the year and about 150 – seasonally. Currently, their number has been reduced by half. At the first and second stages of pasture digression, mesoxerophytes of wide ecological amplitude appear. Afterwards, their sharp decrease occurs, and they are replaced by desert communities represented by *Secale sylvestre*, *Heliotropium dolosum*, *Bassia sedoides*, *B. hirsuta*, *Euphorbia seguierana* and *Cardaria draba*, *Erophila verna*, *Alyssum desertorum*, etc.

Grazing-induced changes of marsh vegetation are typical of Kubanu, Kubansky, Bilgorodsky, Poludenny, and Yermakov islands. At the first stage, the coenotic role of *Phragmites australis*, the dominant species of phytocoenoses of this type of vegetation, decreases. The leading role shifts to the species of the second layer (*Carex elata*, *C. acutiformis*, *C. pseudocyperus*, etc.). Simultaneously, the number of meadow and marsh species (*Symphytum officinale*, *Myosotis palustris*, *Euphorbia palustris*, *Stachys palustris*, *Scutellaria galericulata*, etc.) increases. A significant decrease of boreal swamp species at the first and second stages is practically not observed, and under the influence of prolonged flooding, the total number of species even increases. At the third stage, coenoses made by *Carex* species are formed. They have a greater tolerance to trampling and grazing than *Phragmites australis*. In the absence of a washing regime, swamp coenoses are replaced by communities of *Festuco-Puccinellietea, Bolboschoenetea maritimi*, and *Juncetea maritimi* classes. At all stages of grazing-induced digression, the species composition of phytocoenoses is higher than the initial one, and only at the fourth stage, this diversity decreases.

Grazing-induced changes of solonetz and solonchak vegetation are characteristic mainly of the Zhebryansk seaside ridge and small areas of Kubanu and Yermakov islands, where livestock is concentrated. Soils in the areas of long-term concentration of livestock are so solid and salty that the complete disappearance of marsh and meadow species occurs. The total cover of plants in such plots does not exceed 10–15 %. During the pasture digression, formation of solonetz and solonchak coenoses by species with low food value (*Salicornia prostrata*, *Suaeda prostrata*, *Petrosimonia oppositifolia)* has been noted.

The removal of the grazing impact does not lead to a complete restoration of the vegetation due to changes in the growing conditions. The most endangered is halophyte vegetation, where salinity is intensified by grazing and is a limiting factor in the development of vegetation. Observations of the post-grazing succession of the 2nd year on the Delyukova spit, where solonchak communities formed because of a high concentration of livestock in flooded areas, showed that the formation of low-productive communities of *Juncus maritimus* and *J. gerardii* was the most intensive here.

Changes in communities involving rare and endangered species (*Leucojum aestivum*, *Chrysopogon gryllus*, *Cladium mariscus*, *Dianthus bessarabicus*, *Stipa borysthenica* and all species of the *Orchidaceae* family) are directly dependent on the grazing load. Moderate grazing contributes to the conservation of these species in communities. Overgrazing of meadows leads to the salinization of habitats and formation of communities of the *Juncetea maritimi* class. As a result, the number of *Orchis* species is sharply decreasing, and other species of the *Orchidaceae* family are almost completely disappearing. Overgrazing on sandy dunes causes the formation of loose sands which has a negative effect on *Dianthus bessarabicus*. For communities of *Chrysopogon gryllus* and *Stipa borysthenica*, moderate grazing, especially in the autumn-winter period, has a positive effect on their seed renewal. It restricts the development of shrubs. Moderate grazing of cattle (3–5 heads per ha) also contributes to the conservation of populations of *Leucojum aestivum*.

The mowing-induced vegetation changes. Harvesting hay and collecting reed straw for technical purposes are common local occupations in the Kilyan arm of the Danube Delta. Regular mowing of *Phragmitetum australis* swamp vegetation leads to shifts toward the formation of meadow communities. One-time hay mowing in spring or autumn leads to relatively minor changes in the vegetation cover. Frequent summer mowing has a bigger negative impact and leads to the degradation of communities towards the formation of halophyte vegetation. At the same time, the productivity of mowed areas decreases in proportion to the number of mowings (Dvoretskyi, 2002).

A one-time spring mowing in swamp coenoses increases the vitality of the rare boreal species and the total cover of medium-tall species such as *Euphorbia palustris*, *Lycopus europaeus*, *Lysimachia vulgaris*, *Mentha aquatica*, *Myosotis arvensis*, *Apium graveolens* and species with creeping or twisted stems, which in the absence of mowing were depressed – *Calystegia sepium*, *Galium palustre*. The total cover of the dominant species (*Carex acutiformis*, *C. elata*, *Phragmites australis*) is slightly decreasing.

A one-time autumn extraction of phytomass reduces the cover of edifying species by 25–30 % and increases productivity by almost 1.4 times due to the individuals of the lower layer (Dvoretskyi, 2002). Extraction of phytomass also stimulates the development of rare perennials that have been dormant for 2–3 years in conditions of excessively dense grass, in particular, *Orchis palustris*, a species listed in the Red Book of Ukraine (Dubyna *et al*., 2003).

Winter mowing of *Phragmites australis* in the Kilyan arm of the Danube Delta is carried out on a large scale for the production of building material, as well as for export. Harvesting of reeds in the Danube Delta is one of the types of successive anthropogenic influences. However, it has positive consequences for the preservation of the biodiversity of floodplain ecosystems and the region, in general. Harvesting, carried out in accordance with recommendations, increases the productivity of vegetation and the biological diversity of the region. The lands become accessible and attractive to birds during their migration, the nesting capacity of the land increases, the spawning conditions for fish in vast shallow waters improve, and the seed productivity of plants enhances.

It has been established that the effect of winter mowing of *Phragmites australis* is very similar to that of winter burning of floodplain vegetation during the freezing period. In both cases, there is no compacting effect on the soil, and, consequently, wintering buds (picks) of *Phragmites australis* are not damaged. Therefore, at sub-zero air temperatures, it is possible to use all types of technical mechanisms – combines, mowers, and manual methods of harvesting. Long-term observations of the floodplain ecosystems after winter reed harvesting indicate that the manual method of reed harvesting in the conditions of the Danube Delta is the most acceptable since it does not cause significant damage to soil compaction.

Mechanized harvesting of reed in the Kilyan arm of the Danube Delta is carried out by specialized wheeled harvesters of the Seiga type. At present, with the correct exploitation of combines, namely their one-time passage in accordance with norms, this technique does not cause damage to the soil and even pickles more than 2–3 cm in height. The harvesters can be used regardless of weather conditions, during warm or frosty periods. Six-wheel harvesters are more maneuverable in the conditions of the delta with its small channels (yeriks), overgrown oxbow lakes, and other water barriers. The use of 6-wheel harvesters is also preferable in case of sharp fluctuations in the water levels, which is observed in the Danube Delta as a result of surge phenomena, as well as in the formation of a thin ice cover. A single passage of the harvester causes minimal damage to vegetation. However, multiple passages along the same route create tracks that fill with water. The gradual restoration of the reed is possible only if the mechanized harvesting is carried out only every other year, whereas in the case of deeper disturbances – only every 2–3 years.

It is important to find a compromise between conservation and the various socio-economic uses of reeds in the delta. This can be facilitated by collective agreements, agroecological contracts, or payments for ecosystem services of reed beds (Čížková *et al*., 2023).

In order to preserve, restore and maintain the existing biodiversity of marshes, meadows, steppe, and saline meadows, it is recommended to carry out a one-time spring or autumn mowing every two years. Summer mowing should be used only if it is necessary to form solonetz biotopes in order to maintain biological diversity. In areas where it is impossible or economically unprofitable to apply the phoenisicial influence, it is advisable to burn grass in winter (Dubyna *et al*., 2003).

The pyrogenic vegetation changes. In the Kilyan arm of the Danube Delta, fire is traditionally used as a tool for floodplain vegetation management. Periodic burning was used by the local people to improve the condition of pastures and hayfields, as well as to improve the technical qualities of the reed. They set fire in the winter period (January–February) during freezing or low water levels in the floodplains. Each specific area burned down once every 2–4 years. After the establishment of the Danube Floodplains Nature Reserve and later the Danube Biosphere Reserve, such traditional fires were banned. As a result of the accumulation of dead organic material, *Phragmitetum australis* communities degraded and were replaced by floristically poor coenoses, often with the participation of halophytes. Species diversity and fauna abundance decreased. This problem provoked a heated discussion among supporters and opponents of the use of fire as a factor influencing the biodiversity of floodplain ecosystems, which is currently ongoing. Some information about the dangers and benefits of this regulatory factor has been accumulated on the basis of experimental work.

Particular damage is caused by the spontaneous burning of floodplain vegetation. It often covers large areas and, in addition to direct damage, causes indirect impact. In particular, in the period from September to November 2022, wetland vegetation on the territory of the Stentsivska part of the Stentsivsko-Zhebryansky floodplain burned down on an area of 2,826 ha. Another 73 hectares in the Stentsivska part burned down in March 2023. In total, 2,896 ha in the Stentsivska part were burned by fire in autumn 2022 and spring 2023. In the spring of 2023, wetland vegetation burned down on an area of 1,055 ha in the Zhebryanivska part. In total, the area that burned down in the Stentsivsko-Zhebryanivsky floodplains in the autumn of 2022 and in the spring of 2023 was 3,951 ha.

At the same time, there is also excessive smog in the surrounding area with a negative impact on wildlife and local people. As a result of fires, tree and shrub vegetation burns down. Its restoration is very slow, except for communities formed by *Hippophae rhamnoides*. Pyrogenic changes in the pine forests on the Zhebryansk coastal range are catastrophic. They occur periodically in the summer as a result of inept handling of fire. Restoration of the original vegetation does not occur.

Studies of the effect of the pyrogenic factor on the wetland communities in winter show that there is an increase in vegetative stems of *Phragmites australis* var. *gigantissima* from 3.1 (areas with periodic flooding) to 2.8 times (areas with constant flooding). The total number of stems decreases by 5–10 %. The total number of *Phragmites australis var. flavescens* stems decreases by 3.5 times, and vegetative ones – by 10 %. Plant height increases by 53 % and diameter by 37 %. In both varieties of reed, there is an increase in phytomass (by 26.7 % and 79.0 %, respectively), as well as the number of generative stems. In the marsh communities, species that were suppressed due to excessive accumulation of dead mass, mainly representatives of the *Phragmito-Magnocaricetea* class (*Calystegia sepium*, *Equisetum palustre*, *Glyceria maximal Leucanthemella serotina*, *Rumex hydrolapathum*, *Sium latifolium*, *Stachys palustris*, *Phalaroides arundinacea,* etc.) became abundant.

Summer burning of *Phragmitetum australis* communities leads to catastrophic changes in vegetation with decreasing productivity of phytocoenoses. The greatest changes, in this case, occur in areas with a periodic flooding regime. The phytomass decreases by 20 % compared with the control, the height of the stems and their diameter are noticeably reduced (54.6 % and 43.1 %, respectively). The appearance of species of the classes *Festuco-Puccinellietea*, *Bolboschoenetea maritimi*, diagnosing salinization processes, is observed.

It was found that in conditions of altered hydrological and washing regimes, the pyrogenic factor has a positive impact on swamp vegetation. It provides for the removal of the excess dead mass of floating vegetation, improves the oxygen regime, and contributes to the better germination of seeds and growth of young shoots. As shown by observations of spontaneous burning of marsh vegetation over 10 years, positive results can be achieved by winter burning of vegetation of marsh ecosystems in areas where the volume of accumulated dead mass exceeds 35 %. To restore the ecological role of swamp vegetation, it is necessary to carry out controlled burning, taking into account the linear speed of fire. The choice of methods depends on the characteristics of the territories (area, availability of non-burnable areas, raw material stocks). For swamp vegetation, the method of local and gradual burning is the most appropriate. This method makes it possible to enclose areas occupied by tree and shrub vegetation, to control the process with small human resources, and to ensure fire safety, in particular, in difficult (windy) weather conditions. The frequency of burning must be calculated on a case-by-case basis.

The afforestation vegetation changes. Changes due to afforestation are most pronounced on the Zhebryansk seaside ridge. Afforestation of the ridge has been carried out since 1910. Its original purpose was to anchor the loose sand carried away in wind storms. During this period, forest-forming species changed several times: from *Robinia pseudoacacia* and *Populus deltoides* to *Pinus sylvestris* and *P. pallasiana*. At present, the most common tree for afforestation is *Pinus pallasiana* and, less frequently, *Hippophae rhamnoides*. The sea buckthorn was introduced into the native biotope, which was previously destroyed. But *Pinus pallasiana* did not occur in the Danube Delta. The vitality of pine individuals in many areas was very low. At the same time, large-scale cultivation of this tree species led to an almost complete destruction of the indigenous psammophyte vegetation of the coastal ridge, which was preserved in small islands only in unforested areas (Dubyna *et al*., 2003) (**Fig. 3**).

Fig. 3. *Stipa borysthenica* (the species listed in the Red Book of Ukraine) between artificial *Pinus pallasiana* plantations

It is advisable to use native tree species for afforestation: *Salix alba*, *S.* x *rubens*, *Populus nigra*, *P.* x *canescens*, etc. In depressions of dunes, it is good to plant some shrub species – *Populus tremula, Salix acutifolia, Tamarix ramosissima*, and some *Betula* species. It is also possible to use some tree species characteristic of the Romanian delta, for example, *Quercus robur*, *Fraxinus pallasiana*, *Ulmus laevis*, and other species. This will lead to the gradual restoration of the natural flora, which has great importance not only for the Zhebryan seaside ridge but also for the biodiversity of the delta in general.

As part of the Endangered Landscapes Program, the organization „Rewilding Europe" and Vylkovo Forestry have designed a scheme to reduce pine plantations, plant native species, and develop a recreation area. Afforestation is currently taking place on some riverbed-side ridges of the islands in the secondary delta. Afforestation here is carried out using *Salix alba, S. fragilis,* and *Populus deltoides.* A strip method from 5–7 to 11 rows in various areas according to a 100×250 scheme is used. Afforestation by a monoculture of *Populus deltoides* is typical of Tataru, Daller and Kislytsky islands. This species is also widely used for the afforestation of riparian ridges in the Romanian part of the Danube Delta (Leandru *et al.*, 1960; Tarnavschi, 1970). The number of rows usually depends on the width of the elevated part of the ridge. As a result, same-age areas of dense tree plantations are formed on riverbed ridges, where, in the absence of other factors, restoration changes, characteristic of natural riverine floodplain forest, occur over time (**Fig. 4**).

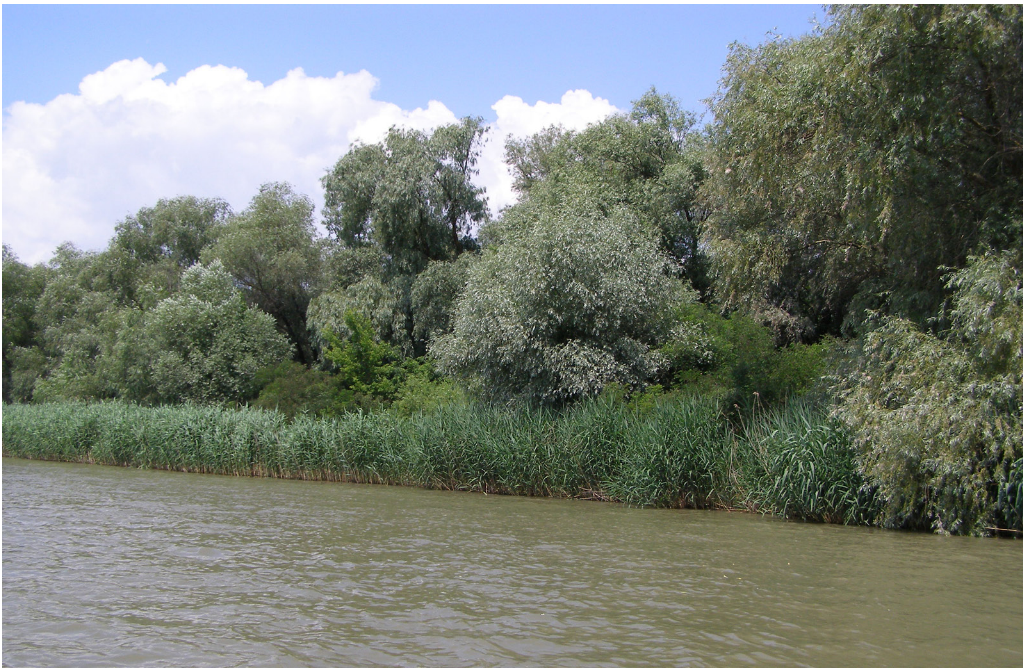

Fig. 4. Fragment of the *Salicetum albae* communities (Starostambulsky mouth)

Biochemical changes. The Kilyan arm of the Danube Delta and the adjacent sea area are strongly affected by the polluted Danube waters. Numerous discharges of sewage, industrial and municipal waste, discharges from agricultural lands and fishponds occur in many places along the course of this huge river; additionally, garbage of various kinds is washed away by flood (Stoica *et al*., 2013; Lazar *et al.,* 2022).

Industrial accidents at hazardous enterprises produce especially negative effects. High concentrations of nitrites, phosphates, iron, copper, chromium, petroleum products, and calcium were found in the Danube water. This led to profound changes in the species diversity and abundance of phytoplankton along the entire sea edge of the Danube Delta (Zaitsev, 1998). In 2003, the discharge of biogenic substances exceeded 900,000 tons per year, which is 40 times more than during the 60s. The number of phenols and hydrocarbon compounds in the delta increased significantly, and the amount of oxygen in the water decreased significantly, especially in the bottom horizon. A large concentration of lipolytic bacteria of the intestinal group (> 1000 cells/cm^3) was traced in the composition of the Danube water (Zaitsev *et al*., 2006). By the beginning of the 90s of the 20th century, the area of the ”blooming” zones of the adjacent waters of the Black Sea had increased by an order of magnitude in comparison with the 1950s. Groundwater contamination with pesticides, nitrates, and nitrites is observed. There are 40 ecologically hazardous facilities at the regional level and the Izmail Pulp factory, which is included in the list of the 100 largest polluters in Ukraine (Program of Integrated Development, 2004). Environmental pollution leads to chemical effects on phytobiota. In general, the productivity of vegetation decreases. Aquatic plants are especially affected.

Successions caused by water pollution depend on its degree and type. As a result, many planktonic and benthic organisms, as well as oxyphilous, rheophilic and relict species disappear from natural biocenoses.

At the initial stages of eutrophication, development of aquatic vegetation increases. With the enhancement of pollution of water bodies and the formation of anaerobic conditions, the diversity of species decreases, at the same time, organic phytomass and phytoplankton increase. As a result of anthropogenic eutrophication, the pH of the environment changes. Due to the mass development of algae, its value rises to 8.2–8.5. At the same time, the light and gas regime of water deteriorates by 25 %, and sedimentation increases.

The most resistant to anthropogenic eutrophication are *Ceratophylletum demersi* and *Potametum pectinati* coenoses. They resist in conditions of low water transparency and high content of organic substances. In hypereutrophic reservoirs, monodominant coenoses of *Potametum pectinati, Najadetum marinae*, and *Ceratophylletum demersi* are formed. In the presence of a constant source of pollution, coenoses formed by species of wide ecological amplitude are replaced by sparse chemotolerant species.

Changes in wetland vegetation under the influence of anthropogenic eutrophication are slow. In general, the formation of coenoses with species of a wide ecological amplitude (*Typhetum angustifoliae*, *Phragmitetum communis*) is common.

Vegetation cover optimization strategy in the Kilyan arm of the Danube Delta. Preservation of the existing natural vegetation, the priority of economic activities that do not cause significant disturbances to ecosystems, and the improvement of the recreational policy are the main strategies for the optimization of the vegetation cover in the Danube Delta. These measures will reduce the existing tension of the ecological regime and contribute to an improved performance of vegetation within the ecosystem (De Groot *et al*., 2002; Tucker *et al.,* 2010; Perillo *et al*., 2019). The direct protection of natural components implies the enlargement of the Danube Biosphere Reserve territory and the improvement of its functional zoning, as well as the creation of a network of nature protection sites of various ranks. It is recommended to combine the protected territories of the Danube Reserve and the Danube Lakes into a single nature protection-recreational-tourist complex with its inclusion in the network of domestic and international tourism objects. The restoration of disturbed territories, which include abandoned reclaimed areas of floodplains and agricultural territories that are not cultivated, should be done.

Land reclamation has one of the biggest negative impacts on the adjacent ecosystems, including the Black Sea water area. It is recommended to reduce reclamation works and pond management and, in the future, to eliminate them. It is necessary to introduce modern technologies into agricultural processes (systems of organic farming, drip irrigation, etc.) and fisheries (resource-saving and industrial fish farming technologies, genetic biotechnology to increase productivity, etc.) (Patel, *et al*. 2021).

Replacing energy-intensive agricultural manufacturing with less energy-intensive ones is another important challenge. A promising type of use of natural phytoresources can be winter harvesting of *Phragmites australis* straw for commercial purposes and for export. In Europe, the use of reeds as an energy crop and renewable eco-material for buildings is still limited, but promising (Čížková *et al.,* 2023). To preserve the whole complex of the Danube Delta biodiversity, it is also important to standardize livestock grazing, hay mowing, periodic mid-winter burning of floodplain vegetation, harvesting of *Trapa natans* fruits, etc.

In the current conditions, long-term and urgent measures should be implemented to protect the phytodiversity of the Kilyan arm of the Danube Delta. Among the urgent measures, the transfer of diaspores of rare plant species from places where they are undergoing transformation to favorable places of growth should be a priority. This applies primarily to species of the neo-endemic floral complex. The territories where they undergo transformation are the coastal areas of Starostambulsky and Kubansky islands. Obviously, there is a need to create a regional center for monitoring adventive species in order to limit their spread, to reduce the habitats of transforming species and, in particular, those that appeared on the territory of the Danube Delta in the last 10–15 years (*Brachyactis ciliata*, *Torulinium ferax*, *Diplachne fascicularis*, *Eclipta prostrata*, etc.), the main arrays of which, except *Brachyactis ciliata*, are still localized in the coastal part of the delta.

Due to the uniqueness of the Danube arena complexes, which have a high number of endemics, it is necessary to implement an absolute protected regime in all areas where they are preserved. The prospective territory for creating reserves is the northern coastal part of the Zhebryansk seaside ridge, which is under recreational threat by the residents of Primorske village.

Another step, which will have a limiting effect on the current transformation of the Kilyan arm of the Danube Delta, is the formation of an ecological network where this natural-historical area would act as the Danube international bilateral key territory. This is in line with the strategy for the formation of the “Green Corridor of the Lower Danube” according to the declaration signed by the Ministers of Environmental Protection of the Danube countries back in 2000 in Bucharest (Petrişor, 2016).

From a political perspective, it is important to create a joint Ukrainian-Romanian comprehensive program for the assessment of hydro-technical construction and economic development in the Danube Delta as an integral natural complex. A joint strategy for the sustainable development of the delta and a plan for preserving typical and rare natural ecosystems is necessary. European policy also involves evaluating the effectiveness of the implementation of existing legislative acts instead of developing new ones (Ignar & Grygoruk, 2015).

The expansion of drinking water supply, wastewater treatment networks, waste management, the use of clean energy, and the participation of local communities in the direct management of wetlands and their resources are examples of measures that urgently need to be taken to improve the living standards of the local communities (Baboianu, 2016; Lazar *et al*., 2022).

CONCLUSIONS

Anthropogenic changes in vegetation occur under the influence of powerful external factors associated with human activity. In the Danube delta, the anthropogenic changes exceed natural in terms of their scale and degree of influence. The main factors of such changes are grazing-induced, mowing-induced, pyrogenic, afforestational and biochemical. The halophytic and halophytic meadow vegetation are most affected by grazing. The steppe and shrub vegetation are influenced by pyrogenic factors, afforestation and forest logging. The phoenisicial factor has an impact on meadow and wetland vegetation. The aquatic vegetation is most endangered by biochemical pollution. The pressure of local anthropogenic factors is enhanced by the impact of global and local natural factors. The complex effect leads to the unification of vegetation, loss of the autochthonous elements, and the formation of unproductive associations.

It has been established that the preservation, restoration, and maintenance of marsh, psammophyte, and salt-meadow communities in the conditions of regulated river flow and climate change can be achieved through the extraction of a certain volume of plant material by mowing, grazing, and winter burning of grass. These measures should be preceded by an assessment of negative outcomes and their trends, as well as careful control over their implementation. A moderate grazing-induced or mowing-induced loading contributes to the increase of the species composition and productivity of communities and the preservation of rare species.

The strategies for optimizing the vegetation cover of the Kilyan arm of the Danube Delta should be directed at maintaining a high level of biological diversity of the Danube Delta, considering the economic interests of local people. This task can be fulfilled only by using traditional types of nature exploitation and land management developed during the historical evolution of the Danube Delta. Positive trends are observed in the implementation of measures to restore the hydroregime of the delta islands and the involvement of wild animals in the rewilding of their vegetation.

The network of nature reserves should also be reviewed. With its greater density in the region relative to other territories of Ukraine, taking into account the ecological vulnerability of floodplain ecosystems, its total area should be tripled, which corresponds to the program documents of the European Green Deal. This important task can be successfully completed only with the further restoration of the ecosystems of the Danube floodplain, which were reclaimed in the past.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest: the authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization, [D.D.]; methodology, [D.D.; T.D.]; investigation, [D.D.; T.D.; L.B.]; data analysis, [D.D.; T.D.]; writing – original draft preparation, [D.D.; T.D.; L.B.]; writing – review and editing, [D.D.; T.D.; L.B.]; visualization, [D.D.; T.D.; L.B.]; supervision, [D.D.]; project administration, [D.D.].

All authors have read and agreed to the published version of the manuscript.

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СУКЦЕСІЙНІ АНТРОПОГЕННІ ЗМІНИ РОСЛИННОСТІ КІЛІЙСЬКОГО РУКАВА ДЕЛЬТИ ДУНАЮ (УКРАЇНА)

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Вступ. В історичному минулому в дельті Кілійського гирла Дунаю переважала заплавна рослинність, характерна для гирлових екосистем, що перебували під впливом помірних згінно-нагінних явищ. Рослинність цієї території була представлена переважно лучними, болотними та водними ценозами. Лісова рослинність займала тільки невеликі площі. На початку минулого століття природні комплекси дельти Кілійського гирла Дунаю зазнали значних антропогенних перетворень. Антропогенні чинники можна умовно розділити на масштабні та локальні. Масштабні чинники після впливу на природні екосистеми дельти призводять до катастрофічних змін екологічного режиму та деградації корінних комплексів флори і рослинних угруповань, локальні (які ще можна назвати сукцесійними, або послідовними) зміни призводять здебільшого до зменшення видового різноманіття, зниження біологічної продуктивності й деградації біоценозів. Основними чинниками послідовної антропогенної трансформації екосистем є пасквальні, пірогенні, фенісиціальні (заготівля очерету і сінокосіння), лісонасаджувальні та біохімічні. Внаслідок довготривалого впливу та великого навантаження на біотопи послідовні зміни переходять у катастрофічні. Навпаки, коли їхній вплив помірний або усунутий, первісна рослинність поступово відновлюється.

Матеріали та методи. У дослідженні використовували багаторічні порівняльні флористичні та фітоценотичні напівстаціонарні методи. Дослідження антропогенної динаміки рослинності проводили прямими методами (на напівстаціонарних ділянках), а також непрямими. До прямих методів належить метод порівняння наявних даних з історичними картографічними та геоботанічними описами, представленими в монографії «Державний заповідник “Дунайські плавні”». Непрямі методи включали реконструкцію динамічних трендів на основі аналізу еколого-ценотичних профілів.

Результати. На основі багаторічних порівняльних фітоценотичних обстежень і напівстаціонарних досліджень виявлено основні локальні сукцесійні антропогенні чинники, що впливають на рослинний покрив дельти Дунаю. Антропогенні зміни рослинності відбуваються під дією потужних зовнішніх факторів, пов'язаних з діяльністю людини. У районі дельти антропогенні зміни за своїми масштабами та ступенем впливу перевищують природні. Основними чинниками є пасовищні, пірогенні, фенісиціальні, лісонасаджувальні, біохімічні тощо. Галофітна та засолена лучна рослинність прибережних територій найбільше потерпають від випасу в місцях концентрації копитних тварин. На піщано-степову та чагарникову рослинність впливає пірогенний фактор і насадження лісових культур. Вплив фенісиціального фактора проявляється у впливі на лучну та болотяну рослинність. Водяна рослинність найбільше потерпає від біохімічного забруднення. Тиск локальних антропогенних факторів посилюється впливом глобальних або локальних природних чинників. Комплексна дія локальних антропогенних і глобальних кліматичних факторів на угруповання призводить до їхнього збіднення, втрати автохтонних елементів і формування непродуктивних угруповань. Встановлено, що помірний антропогенний вплив сприяє збагаченню біорізноманіття дельти. Найбільш загроженою є піщано-степова та псамофітна рослинність із представниками псамофільно-літорального неоендемічного понтійського флористичного комплексу.

Висновки. Запропоновано стратегію оптимізації рослинного покриву Кілійського гирла Дунаю. Збереження, відновлення та підтримання рослинності дельти в умовах зарегульованого стоку річок і зміни клімату можна досягти вилученням певного об'єму рослинної сировини за допомогою косіння, випасання та зимового спалювання трави. Цим заходам має передувати оцінка негативних змін і їхніх тенденцій, а також ретельний контроль за їхнім виконанням. Помірне пасквальне та фенісиціальне навантаження сприяє розширенню видового складу та підвищенню продуктивності угруповань, збереженню рідкісних видів.

Ключові слова: локальні зміни, динаміка, рослинні угруповання, Кілійське гирло Дунаю, Україна

Received / Одержано 07 January, 2025 | Revision / Доопрацьовано 05 February, 2025 | Accepted / Прийнято 17 September, 2025 | Published / Опубліковано 24 September, 2025