USING THE RULES OF NATURAL RECOVERY OF ECOSYSTEMS FOR THE PROCESS OF REVEGETATION AND TERRAFORMING

Khomiak Ivan, Vasylenko Olha
PhD, docent associated professor, khomyakIvan@gmail.com
PhD, docent associated professor, o.vasylisa@gmail.com
Zhytomyr Ivan Franko State University

Despite all the technological advances and the development of science humans remain deeply integrated into natural ecosystems. It is not just about a network of mediated connections, the destruction or transformation of which will lead to the death of humanity. It also means direct dependence on natural ecosystems with anthropogenic subsidies, such as agricultural or forestry. Statements that man is capable of destroying all living things on the planet seem too self-confident and anthropocentric. We will destroy ourselves sooner than we reach the dangerous level of final destruction of the entire biosphere. Numerous natural disasters of a planetary or cosmic nature, which we are now massively observing in outer space, are able to finally destroy our biosphere much earlier and more efficiently than we ourselves. If we want to survive in a changing and hostile universe, we must set ourselves three goals: an increasingly accelerated and deep study of the surrounding world, the colonization of outer space, and the creation of an optimal natural environment. This process will include both the restoration of ecosystems disturbed due to our activities and the creation of new self-sufficient ecosystems outside the Earth's borders.

It is possible to single out general laws, the observance of which increases the efficiency and reliability of the processes of nature restoration, reclamation, and terraforming, despite the great diversity of environments, ecosystems, and varieties of their dynamics. Models for these activities are the processes that occur in our ecosystems. By observing their reaction to the disturbance, we can crystallize the most general regularities, which can later become useful for our restorative activity. Model territories for such research are abandoned quarries or their elements that are not actively exploited, fallows, abandoned settlements or structures, and damage to the earth's surface as a result of military actions. During the survey of such objects, we created standard geobotanical descriptions, which were analyzed using synphytoindication methods.

Restoration of natural vegetation occurs simultaneously under several scenarios with the predominance of those that are most favored by environmental conditions (Kotsiuba et al. 2023). Here, different types of extremophile recovery lines can exist in parallel, along with attempts to immediately transition to the formation of more complex groups of producers, for which a seed bank or seed diaspora from neighboring undisturbed ecosystems is used.

All areas of our planet disturbed by human activity or catastrophic natural processes always contain autotrophic microorganisms. These are mostly unicellular algae and cyanobacteria. They are well adapted to live in extreme conditions, that not suitable for most other producers. In this case, they remain for a long time in this area, being the energy base for the ecosystem. If the conditions are more favorable or change towards the optimum for other multicellular organisms, then such groups of unicellular extremophiles are displaced by other species. In this case, instead of resistant to a low amount of moisture and nutrients (most often epiphytic), one-celled producers resistant to shading (most often epiphytic) appear.

Over time, a symbiotic formation is formed between these unicellular or colonial autotrophs and lichenophilic fungi. In the case when we are talking about dry and well-lit ecotopes without a significant projective covering of higher vascular plants, lithophilic or geophilic lichens are formed. In another case (moderate humidity, shading, the presence of a significant area covered by higher vascular plants) – epiphytic lichens. In some cases, we observe colonies of lichneophilic fungi, which for some reason did not establish a connection with algae or cyanobacteria. Here we observe the rule of change of photosynthetic phytomass in the process of restoration of ecosystems, which accompanies autogenic succession (Khomiak, 2019).

Initially, the lichen group has a small area and is represented by crustose and leprose biomorphs, which have the lowest indicators of the maximum accumulated biomass. Then, if environmental conditions allow, folios forms appear and begin to dominate. If we are talking about vertical monoliths of crystalline rocks, then at this stage a catastrophic climax will be formed due to a critical slowing down of endoecogenesis. Where there is a fine-grained substrate of sedimentary rocks, lichen groups of representatives with a fruticose form develop.

The next stage of restoration of natural ecosystems on loose sedimentary rocks is the formation of moss communities. Generally they gradually replace groups of fruticose lichens. This process occurs gradually with the formation of a dynamic ecotone between species (Harbar, at al. 2021, 2023). This happens on different types of places. For example, in the crevices between monolithic vertical crystalline blocks or over relatively horizontal blocks that are covered with dust; on top of well-drained sand hills or on the vertical slopes of loess ravines and gullies. The following classes of plant groups are formed here: *Cladonio digitatae-Lepidozietea reptantis, Ceratodonto purpurei-Polytrichetea piliferi* та *Psoretea decipientis* (Prodrome… 2019). With the appearance of a high multi-tiered cover of higher vascular plants, their characteristic species are replaced by shade-tolerant and epiphytic ones.

Grass wastelands are often formed together with moss-lichen ecosystems, which create different types of ecotones between them: spatial, topological, typological, including dynamic. The autotrophic block of such ecosystems is the vegetation of classes *Sedo-Scleranthetetea* and *Koelerio glaucae-Corynephoretea canescentis*.

If enough time passes and the tree-shrub vegetation does not have a continuous cover, then meadow-shrub ecosystems with autotrophic blocks in the form of the *Calluno-Ulicetea* and *Nardetea strictae* classes appear.

In more favorable conditions, especially where the substrate is capable of retaining capillary moisture without forming a watertight horizon, ecosystems with synanthropic vegetation are found in the first stages of recovery. This almost always occurs in fallow or disturbed soil areas adjacent to agricultural or urban areas. The first to appear here are segetal groupings of the class *Stellarietea mediae* and ruderal orders *Agropyretalia intermedio-repentsis* (class *Artemisietea vulgaris*).

They use different approaches to adaptation in disturbed ecosystems. The former has an advantage due to the combination of individual resistance with high intensity of seed production. Others use a more flexible and complex strategy. They use islands with more nutrients and moisture and extreme areas that house parts of their rhizome-bound cloned superorganism. On the "island," there is high competition for light, but there is a small share of available power cells, and outside it the competition is not as fierce or completely absent. Those located on the "island" provide nutrients to the common rhizome system, and those located outside of it provide the products of photosynthesis. In addition, numerous recovery buds on the rhizome itself allow it to quickly restore a new organism after a disturbance. The rest of the ecosystems with an autotrophic side in the form of coenoses of the *Artemisietea vul*garis class appear somewhat later and require more favorable edaphic conditions.

At this stage, edaphic conditions and the level of anthropogenic pressure determine the course of restoration and its main directions. For example, the penetration of the production zone below the aquifer or the formation of layers of waterproof substrate leads to the formation of various communities of the coastal-aquatic type. This can happen even if there is no permanent or temporary reservoir. Thus, on the slopes of dumps at such stages of autogenous succession, we often observe groups formed by *Phragmites australis* (Cav.) Trin. ex Steud. or *Bidens tripartita* L. The latter spreads under the condition that its seeds are transferred to the dump along with the soil, or the level of nitrates and ammonium salts increases. In this case, typical habitats with an autotrophic block are formed in the form of a class of groups of *Bidentetea tripartita.*

Under favorable edaphic conditions and in the absence of significant anthropogenic pressure a shift from the ruderal or wasteland phase to the grass-heath, grass-shrub, shrub, or forest-shrub phase may occur. The conditions for this shift formed starting from the first year of restoration. However, different areas take different amounts of time for these stages to become apparent. During this stage, it is common to find grasses, forests, or shrubs belonging to ecosystems characterized by autotrophic classes such as Epilobietea angustifolii, Franguletea, Rhamno-Prunetea, Robinietea, and

Salicetea purpurea. Environmental conditions have a significant impact on the type of ecosystems at this stage. In the most humid conditions, groups of *Salicetea purpur*ea and *Franguletea* are formed. In the driest *Epilobietea angustifolii* and *Rhamno-Prunetea*. Meanwhile, certain associations within the latter two classes exhibit reduced reliance on the long-term moisture conditions.

In cases where the disturbed area experiences significant seed dispersal pressure and possesses conditions conducive to forest development, native forests, rather than derived ones, may emerge. In over moistened places, it can be alder forests of the *Alnetea glutinosae* class, and in relatively dry places pine forests of the *Vaccinio-Piceetea* class. Such a phenomenon is extremely rarely observed for young broad-leaved forests of the *Quercetea robori-petraeae* and *Carpino-Fagetea* classes. These groups form forest stands of the last stages of autogenic succession before the climatic (thermodynamic) climax. Such a climax is formed in specific environmental conditions, which we call "climactic optimum". These are the edaphic and related orographic conditions in which such forest ecosystems will be able to accumulate the maximum amount of energy and store it for the maximum time. Very rarely in severely disturbed ecosystems are there environmental conditions that correspond to the climactic optimum.

Typically, this can be accomplished either through specific interventions or through an extended autogenic succession process, during which the edaphotope undergoes gradual changes over centuries due to endoecogenesis. When considering the spectrum of ecosystem services a restored natural area can offer, mesotrophic water bodies (belonging to the plant community class Potamogetea), oligotrophic swamps (of the plant community class Oxycocco-Sphagnetea), and primeval forests (of the plant community class Carpino-Fagetea) emerge as the indisputable leaders. Ecosystem services are not merely a concept advocated by environmentalists; they represent tangible assets that can be quantified and harnessed.

When initiating the reclamation process, the initial step is to assess whether it would be more economically advantageous to facilitate the restoration of natural ecosystems. It is essential to determine whether it would be more cost-effective to allow nature to regenerate with minimal intervention, to actively influence the establishment of an ancient oak forest, or to consider reclamation efforts, which entail restoring agriculture or cultivating commercial timber in the form of pine forest plantations. Such a principle should work not only when we restore the disturbed ecosystems of our planet, but also when we begin to master lifeless alien worlds.

To conduct such calculations, a solid theoretical foundation is imperative. It should be a model of natural restoration of ecosystems in territories disturbed by direct or indirect anthropogenic activity.

The basis for forecasting the pace and direction of ecosystem dynamics can be a change in the amount and age of above-ground phytomass. It allows predicting the duration of certain phases of restoration of natural vegetation. For example, the stage of derivative forests can last up to 70-90 years. Sometimes it takes 150-250 years to form communities of climatic (energy) climax. To establish the vector and pace of the dynamics of settlement of the disturbed soil, we use data on the time since the disturbance and the indicator of natural dynamics at the time of the survey.

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