Industrial Botany in the Modern Era

*Andrej Kuprijanov**

Kuzbass botanical garden Federal Research Center of Coal and Coal Chemistry SB RAS, Kemerovo, Russia

Abstract. Scientific and technological progress has enabled humanity to create an unprecedented level of comfort, underpinned by the global exploitation of virtually all planetary resources, including plants. Humanity has paid an exorbitant price for its prosperity – it has destroyed the resilience of natural ecosystems and, consequently, the conditions for the survival of humankind. We live in an era of global ecological crisis; without finding the right way out, we risk losing the ability to inhabit planet Earth. The technocratic development of civilization is killing nature and killing humanity itself. Industrial botany aims to preserve habitats and the biosphere. Key problems facing industrial botany include studying the processes of revegetation on mine dumps and developing nature-like technologies for accelerated plant restoration on mine dumps; studying the dynamics and status of invasive species populations under anthropogenic and technogenic impacts on vegetation; conserving floristic diversity *in situ* and *ex situ* in many industrial regions; and developing a system of specially protected areas.

Results and Discussion

Botany is the science of plants.

Industrial botany is a complex branch of botany that studies the state of plants and plant communities under specific conditions of anthropogenic and technogenic impact [1].

Scientific and technological progress has allowed humanity to create an unprecedentedly comfortable existence, based on the global use of almost all the planet's resources, including plants. Humanity has paid an exorbitant price for its well-being - it has destroyed the stability of natural ecosystems, and consequently, the conditions for preserving the environment for humans themselves. We live in an era of global ecological crisis; without finding the right way out of it, we are losing the opportunity to live on planet Earth. The technocratic development of civilization is killing nature and killing humanity itself.

Numerous scientists contend that the ecological crisis has positioned humanity at a bifurcation point, a critical juncture for the biosphere. Beyond this point, the future trajectory of the biosphere becomes uncertain. Even minor shifts in events at this critical juncture could drastically alter the course of evolutionary development.

* Corresponding author: kupr-42@yandex.ru

The first industrial revolution, beginning in the mid-19th century, drove a surge in European coal mining to meet escalating energy needs. This rapid expansion resulted in extensive waste disposal and significant environmental pollution.

The recognition of the need to rehabilitate damaged lands and restore their economic and ecological functions emerged only in the mid-20th century. UN data from the early 21st century indicates that as much as 40% of the global land surface has undergone degradation. These degraded lands are prevalent across all terrestrial biomes, from deserts and tropical forests to urban remnants. Experts highlight that these areas experience the most rapid decline in biodiversity. Furthermore, land degradation exacerbates climate change by diminishing the Earth's capacity to sequester carbon [2].

As of January 1, 2022, the land fund of the Russian Federation amounted to 1712.5 million hectares. In terms of arable land per capita (0.79 hectares), Russia is among the top five countries and surpasses the global average by a factor of 3.3. While this is positive, indicating a substantial land resource, the agricultural land area has been shrinking in recent decades. Between 1990 and 2020, it decreased by 258.4 million hectares [3].

The growing mining industry in Russia is resulting in a continuous expansion of waste dumps and open pit mines, leading to extensive land degradation. In 2020, the total area of disturbed land reached 1.1 million hectares. The Kemerovo region, with its vast coal reserves, has experienced the most significant impact, with waste disposal sites occupying nearly 150,000 hectares.

At the Kuzbass Botanical Garden, technologies are being developed to restore near-natural communities on waste heaps in a short period of time.

The technology for restoring vegetation on industrial waste dumpsites involves harvesting a grass-seed mixture by mowing the above-ground mass of plants in early summer (to capture seeds of early-flowering plants) and late summer (to capture seeds of late-summer plants) on donor sites. The grass-seed mixture is then shredded and applied to the waste heap in late autumn. Research conducted since 2014 has shown that the application of this technology leads to the formation of meadow-steppe communities comprising 30-40 species of native flora. This technology stimulates the formation of near-natural plant communities.

The technology of revegetating mine dumpsites involves removing the fertile topsoil layer, complete with root systems, seeds, and living plants, from areas destined for excavation. Bypassing the stockpiling stage, this topsoil is directly applied to previously formed dumps. By the fifth year, the number of species within the quasi-natural communities reaches 37-47, which is almost equivalent to the species richness of natural dry meadows. In terms of quantitative indicators, the quasi-natural communities established during spoil revegetation are nearly as developed as the zonal meadow communities of the Kuznetsk Basin [4].

Most researchers attribute the sharp increase in temperature to the growing concentration of carbon dioxide in the atmosphere, primarily due to human activities such as burning coal and other fossil fuels. The destruction of natural ecosystems and the release of CO_2 into the atmosphere accelerate global warming, which could lead to irreversible and potentially catastrophic consequences for humanity.

This is where the potential to increase carbon sequestration by common pine plantations on mine dumps arises. Pine is a record holder for rapid growth and resilience when cultivated on mine dumps. Young pine plantations can sequester up to 4 tons of carbon per hectare. Pine trees continue to increase biomass even in the mature forest stage – at the age of 60 years. After that, the rate of biomass accumulation decreases.

At the same time, there is no inevitable emission of carbon dioxide into the atmosphere from the substrate of the rocks that make up the mine dumps. Mine dumps with pine plantations become carbon farms for many decades, ensuring carbon sequestration. By

changing the planting density of pine, it is possible to regulate the rate of carbon accumulation in the forest stand [5].

One of the most important problems facing industrial botany is the study of the processes of overgrowth of industrial dumpsites and the development of nature-like technologies for the accelerated restoration of vegetation on mine dumps.

Globalization in all its manifestations, anthropogenic transformation of flora, and global warming have led to the introduction of alien species into natural ecosystems. A worldwide inventory of alien species was conducted under the leadership of Professor Mark van Kleunen [6].

Scientists analyzed data on the presence of alien species in 480,000 regions of the Earth (the surveyed areas account for approximately 83% of the Earth's surface). According to researchers, humanity is responsible for the spread of at least 13,168 plant species (about 3.9% of the world's flora) beyond their natural ranges.

For Siberia, this problem is becoming increasingly urgent due to global warming and industrial development. The dynamics of invasive species dispersal are extremely high and require careful monitoring studies on the dispersal of these species, the study of their biology, and the development of measures to contain them. In 2016, the "Black Book of the Flora of Siberia" was published, which included 56 invasive species [7], but the dynamics of the dispersal of alien species and their introduction into natural systems are extremely high and require constant monitoring of this process.

The study of the dynamics and state of invasive species populations under conditions of anthropogenic and technogenic impact on vegetation is currently a most important task of industrial botany.

Towards the end of the 20th century, humanity recognized the global significance of biodiversity for the preservation of human habitats. Species diversity, shaped by a long evolutionary process, forms the foundation of ecosystem and biosphere integrity. The loss of even a single, seemingly "insignificant" species can disrupt this integrity and lead to ecosystem collapse. As natural communities become less diverse, their resilience decreases, along with their global role in carbon sequestration and organic matter production. The extinction of any species represents an irreversible loss of unique genetic information. Every species, even those not currently utilized by humans, holds potential value, as we cannot predict which substances, found in plants for example, humanity might require to meet its needs and ensure survival in the future.

A century ago, the threat to the existence of individual species and ecosystems was not as severe as it is today, when population growth and the consequences of human activities are causing irreversible changes to the planet's ecosystems, posing a threat to the very existence of the human population.

In 1992, at the Rio de Janeiro Earth Summit, the Convention on Biological Diversity was adopted. The primary goal of the Convention is the conservation of biological diversity, the sustainable use of its components, and the responsibility of each state for the conservation of biodiversity within its jurisdiction [8].

The conservation of biodiversity *in situ* and *ex situ* in many industrial regions, the development of a system of specially protected areas is becoming the paramount task of industrial botany at the present stage.

In this regard, the role of botanical gardens is increasing, as they bear the responsibility of preserving floristic diversity *ex situ* and developing technologies for restoring populations of rare and endangered plants in lost habitats [9].

In industrially developed regions, botany in its pure form practically ceases to exist; the influence of technogenic and anthropogenic factors can be traced in almost all floristic studies. The tasks of industrial botany are constantly expanding and acquiring great social and economic significance. Practically all botany in the 21st century is becoming industrial.

Conclusion

Industrial botany is a complex branch of botany that studies the condition of plants and plant communities under specific conditions of anthropogenic and technogenic impact. It aims to preserve habitats and conserve the biosphere. The most important problems facing industrial botany include studying the processes of overgrowing waste dumps and developing nature-like technologies for the accelerated restoration of vegetation on waste dumps; studying the dynamics and state of populations of invasive species under conditions of anthropogenic and technogenic impact on vegetation; preserving floristic diversity *in situ* and *ex situ* in many industrial regions, and developing a system of specially protected areas.

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