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**Research Article**

# OAK Forest Biocoenoses: Overview of the Issue of Their Environmental Sustainability and Possible Ways to enhance it

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**ABSTRACT:**
BACKGROUND: The article deals with the concept of forest biocoenosis stability, lists and characterizes the factors that can destabilize the forest ecosystem. RESULTS: The authors consider the long-term and intensive human impact to be the main destabilizing and inhibiting factor for Russian oak forests, the process that involves negative selection of oak and its multiple cloning through shoot reafforestation. The authors confirm this statement with their own studies and numerous publications. The second most important destabilizing force for oak forests is a group of abiotic factors, the most influential among which are extreme weather conditions and water table fluctuations. The third most important force destabilizing oak forest biocoenoses, according to the authors, is a complex set of biotic factors, manifesting themselves mainly in outbreaks of species parasitizing oak trees. CONCLUSIONS: The article enumerates a number of fundamental environmental mistakes in oak forest regeneration and cultivation, such as the overrepresentation of shoot reafforestation, clear fellings, the conflict between plantation and biocoenosis forestry, etc.). Lastly, a conclusion about the specific Russian oak forests stability is given. The authors give detailed recommendations on how to reduce the destabilizing effect of these environmental factors and anthropogenic activities in oak forests.

**Keywords:** oak forests, forest biocoenosis stability, forest ecosystems, recreational impact, oak forest regeneration.

## INTRODUCTION

The stability of an ecosystem (and oakery undoubtedly is a complex multi-level biogeosystem) implies its ability to return to its original state of dynamic equilibrium after being disturbed by an external force[1-4].

Therefore, potentially destabilizing factors for a given forest biocoenosis and its sustainability potential should be taken into careful consideration when we try to improve the sustainability of a forest stand.

## MATERIALS AND METHODS

Scientists have long known a range of factors which can throw natural ecosystems off balance. We suggest that these factors be clustered into 3 well-defined groups on the basis of the degree of harm inflicted on oak forests.

For most of the territory of Russian oak forests, the first group of factors is **the long-term and intensive anthropogenic impact**. *It has continued throughout the millennia virtually* *uninterrupted*[5, 6]*, manifested mainly in the deliberate withdrawal of the most productive part of forest stands.* This is, basically, a negative selection, which has reduced the oakeries' ability to resist destabilizing forces. In addition, since it has happened through a succession of *clear fellings*, which trigger coppice regeneration, it has led to the oak's evolutionary stagnation. As a result, oak has lost its ability to mutate in the process of sexual reproduction and, therefore, to adapt to changing environmental conditions[7].

Another extremely destabilizing factor in this group, that can cause degradation of oak forests, has been (again, for millennia) *unrestrained cattle grazing*[8, 9].

This situation is further aggravated by biodiversity decline and soil compaction in oak forests which is due to rapidly increasing *recreational loading.*

*Human activities related to forestry* have also made a significant contribution to the weakening of oak forest biocoenoses. Among these activities are the following: untimely improvement cuttings (especially in young natural and planted forest stands), untimely final felling, disregard for the rules of selection of associated species corresponding to the ecological and biological characteristics of oak, disregard for zoning principles, non-regulation of the number of wild ungulates and so on[10].

However, it should be noted that the majority of researchers do not consider the anthropogenic impact to be the number one reason for degradation of oak forests. In our view, this is due to the fact that until recently there wereno in-depth studies giving an idea of the nature, dynamics,and volume of oak forest exploitation in ancient and medieval times. Based on the works of numerous authors[5, 9, 11-19]and our own research, we have come to the conclusion that for oak forest biocoenoses of the European part of Russia the anthropogenic impact is the decisive factor and the reason why natural climate extremes nowadays lead to the mass death of the oak or decrease of its role as a forest-forming species.

The issue is covered in greater detail in the monographs "Sanitary clear cuttings: theoretical grounding and optimization"[7], "Degradation of oak forests in the Central Black Earth Region"[6], "Outward signs of the English oak pathology"[20] and in a number of articles[21, 22].

The second most important destabilizing force, based on the frequency and influence on oak forests, is **a complex of abiotic factors**, largely consequent upon extreme weather conditions and water table fluctuations.

Unlike anthropogenic factors, development of abiotic factors correlates much more strongly with changes in the state of oak forest biocoenoses, that's why a large number of researchers consider them to be the root cause of degradation processes in oak forests. Although the mere fact that oak appears to be the only woody species under stress indicates that it had been previously weakened by something and became unstable before having been exposed to the limiting factor and is,therefore, less viable than associated species. Thus, abiotic factors are at least a secondary cause of degradation processes in oak forests.

The role of abiotic factors in the weakening and destabilization of oak forests biocoenoses and the mechanism of their oppressive and destructive impact on oak forests is quite well understood and reported in numerous academic writings, according to the bibliography by A. L. Musievskiy[23], only in the Russian language the number of published research papers on this topic is more than 850.

The third force destabilizing oak forest biocoenoses is **a complex of biotic factors**, which manifest themselves mainly in *outbreaks of species parasitizing oak trees.*

Oak has a vast number of well-specialized parasites; it's one of its ecological features. Even oak's closest relatives – elm, beech,and hornbeam – have an order of magnitude smaller number of parasites[24]. On the one hand, this fact indicates the evolutionary weakening of oak as a biological species, and on the other hand, the reduced stability of those forest biocoenoses where oak is essentially the main forest-forming species.

Besides, *because of their ecological weakness oakeries often become a breeding ground for pests and diseases.*

Unlike the previous two groups of destabilizing factors, the impact of biotic factors depends directly on the state of forest biocoenosis. Mass multiplication of tree pests is primarily subject to ecological and biological weakness of forest biocoenosis and its components, while extreme weather conditions play only a secondary role[25, 26].

Therefore,*itshould be decided first what kind of destabilizing factors is crucial for the stability of oak forest biocoenoses and which one should be taken care of first* in order to improve the stability of a given biosystem.

If the crucial one turns out to be **the group of anthropogenic factors**, then the biological capability of a system plays only a secondary role. It is well known that man can damage or even destroy any natural ecosystem. Most often, however, it's done unintentionally and generally negative human impact on natural ecosystems is due to ignorance rather than conscious choice, or, to be more precise, due to the lack of clear criteria for the allowable anthropogenic impact that does not threaten the stability of an ecosystem with irreversible damage.

Therefore, in order to improve the forests' resistance to anthropogenic impact, it is necessary to clearly *define the ecological thresholds* (better yet leaving enough "buffer") *for forest biocoenosis*, beyond which men should intervene only for regeneration purposes.

In Russia, there always have been recommendations, guidelines,and rules on this issue, at least since the forest management was formed[16], but all of them have a whole range of major shortcomings from the environmental and silvicultural points of view.

So, *despite the fact that microcoenotic structure of natural forest biocoenoses has been explored in detail, it still isn't being taken into account when developing a set of forest technologies*. As a result, any selective cutting can disrupt the populational, biomass, energy and ecological balance of the forest ecosystem. If an ecosystem retains its homeostatic properties, its first reaction to the disruption isn't to restore the species taken or to regain the biomass but to restore the balance by displacing the excessive components of the microcoenosis. In other words, *any modern selective cutting impoverishes forest ecosystems and makes them less stable*.

Another **ecological nonsense in practical forestry is the tradition***to create forest stands on the basis of the same principles as for agrocoenoses (i.e. even-aged plantations of certain composition and planting scheme) and to base the growing technology on principles of self-regulation and natural stability of both individual species and biogeocoenosis as a whole*. As a consequence, the lifespan of forest plantations almost always turns out to be shorter than that of natural forests of the same type. Plantations also happen to be less resistant to biotic factors. A striking example of this fact can be pine plantations in the forest-steppe zone, which mostly tend to degrade at the age of 50-70 years, not being able to withstand the impact of annosum root rot and pests.

Moreover, *the reliance on clear felling and coppice regeneration in oakeries was definitely a mistake from an ecological point of view*. The oak's ability to regenerate by shoots was evolutionarily designed for young trees in order to enable them to quickly fill the gaps in forest stands after natural disasters (mainly windbreak and snowbreak). Complete shoot reafforestation doesn't happen in nature. And artificially created coppices result in low-quality stands, the shorter lifespan and, at the mature age, in subsequent degeneration of plantations into aspen, lime, maple, ash forests and so on.

The "longevity" of the above-listed forestry shortcomings, which cause reduced sustainability of forest biocoenoses, is due to the preponderance of forest utilization over forest conservation and reforestation and to the lack of objective ecological justification for most current silvicultural operations.

Therefore, improvement of forests' stability is more of a moral and legal problem than an ecological and biological one. On this premise, in our opinion, the main silvicultural challenges related to forest conservation and enhancing resistance to human impact can be summarized as follows:

– **to ascertain the environmental status** of each specific forest biocoenosis (and not the whole forest area), that is, the pattern, acceptable level and order of its possible use;

– **to develop objective environmental criteria** against which the sustainability of forest biocoenoses and ecosystems should be assessed;

– **to form reference ecosystem models** for every forest site type;

– **to determine the actual level of environmental sustainability** for each specific forest ecosystem before the implementation of any silvicultural operation;

– **to make a forecast of environmental deformations** that may occur under the influence of the planned operations.

– **to create an effective monitoring system** to monitor compliance with environmental requirements while performing the silvicultural operations.

In order **to improve the forest biocoenoses' resistance to abiotic factors** we also need to pay more attention to complying with the technology of silvicultural works than to strengthening the internal bioresources of forest biocenosis components.

If we try to prioritize abiotic factors according to their impact on oak forest biocoenoses, they rank as follows:

– droughts (the persistence of high summer temperature combined with the lack of precipitation);

– extremely low winter temperatures;

– spring frosts;

– raised water table;

– water table fluctuations;

– whirlwinds and hurricanes;

– heavy snow and glazed frost;

– hail storms.

Only communities with optimal environmental sustainability potential in this forest site type can resist the impact of all these factors in the best way possible. In other words, we probably won't be able to improve the stability of a forest community better than nature has done it by a thousand year co-evolution of its components. Accordingly, ***in order to improve the forest stands' resistance to abiotic factors foresters above all things should create stands that are closest to the indigenous forests that could have grown in this forest site type in this climatic period***.

To a lesser extent, this applies to forest plantations. Even-aged and created according to the certain planting schemes, which most of the time are far away from the actual spatial structure and tree species composition, forest plantations are flawed by default and, therefore, less stable than self-formed forest plots. That's why if we create artificial forest stands we should also artificially create and maintain certain parameters, such as species composition, crop density, vertical and horizontal structure, etc., in accordance with those of natural forest communities in this area.

*The crucial difference between the methods of increasing the resistance of natural and artificial forest stands to abiotic factors is that in the first case we should do as much as possible to preserve and activate the self-regulatory (or homeostatic) functions of a forest community, while in the second case we have to take over the responsibility for the process and make constant adjustments in order to form a sustainable community*.

But for the moment the best-developed and the most feasible way of improving the environmental sustainability of forest stands and biological sustainability of individual trees is **to increase the resistance of forest communities to biotic factors**.

As is well known, consumers of all types, including pests and forest diseases, are natural components of the forest community and their ecological role is indispensable. Not only they transform biomass for its accumulation and further mineralization but they also are very effective catalysts for the evolutionary adaptation of all producers to changing external conditions.

That is,the mass multiplication of a phytophage or, let us say, wood-decay fungus indicates that, first of all, the species parasitized by this pathogenic organism has been severely weakened and has become uncompetitive against other tree species. As a result of this process, the species oppressed by the parasitic organisms either will be pushed out of the stand or, on the contrary, will get stronger due to the immune boost and regular fertilization caused by increased mineralization of organic matter by phytophages.

So when it comes to the improvement of the forest stands' resistance to biotic factors the major concern appears to be the correct assessment of the true state of the given species which will enable us to make an informed decision about whether to intervene in the natural process of interspecific competition in the forest community and, if so, how exactly it should be done.

The modern forestry has a wide array of tools and technologies for this intervention. The foresters can destabilize or even destroy a centre of infection or the pest harborage area using chemicals, biological or pyrethroid control agents as well as a range of silvicultural operations. They also can stimulate the biological stability and resistant activity of the species itself, using fertilizers, a variety of agents that enhance the immune resistance of the species and various agricultural and silvicultural methods.

**RESULTS**

In order to understand the whole picture of forest ecosystem stability we need to consider evolutionary means of addressing destabilizing factors used by the main components of the ecosystem at various organization levels: organismal, populational, biocoenotic and the level of the whole ecosystem.

*At the organismal level*, the stability of each individual organism is ensured by a number of specific adaptation devices. For trees the most significant ones are:

– an excess of nutrients stocked in trunk, root and branch tissues;
– photosynthetic potential, unrealizable under normal conditions;
– resistant capacity – the ability to suppress pathogens with the use of phytoncides, tree sap, gum turpentine, etc.).

*At the populational level* the most significant adaptation devices are:

–species variability, which ensures polymorphism and allows the population to adapt to changing external conditions;
– excessive fertility potential of the population, which is by 2-6 orders of magnitude higher than the real resource potential of the biotope;
– age structure, which helps a population to quickly make up for the shortfall in its number of individuals.

*At the biocoenotic level*:

– Biodiversity;
– Variety of consorted links;
– Vertical layering;
– Succession processes through which the leaf-area index and the chlorophyllous index are constantly changing;
– Variety of ecological niches in use.

*At the level of the whole ecosystem*:

– The ability of a community of living organisms to influence microclimatic conditions, especially temperature and water ratio;
– Its ability to transform a rigid environment, for example, humus content and mechanical and chemical composition of soil;
– Spatial structure.

As we can see, the problem of sustainability of oak forest biocoenoses is complex, ambiguous and multifaceted, and we need to take into account a lot of different factors in order to restore our oakeries. Otherwise, we might lose the remaining oak forests within the next 100 years.

**DISCUSSION AND CONCLUSION**

From the data provided the following conclusions may be drawn:

1. Ecological stability of oak forests (or any forest biocoenosis) should be considered as a complex of biological and ecological adaptations of its components to groups of biotic, abiotic and anthropogenic factors.
2. Oak, as a tree species and the main edificator of oak forest biocoenosis, has well-defined and very specific environmental sustainability features, one of which being the fact that it is severely weakened both biologically and evolutionally.
3. In order to enhance the environmental sustainability of oak forests, we should meet such challenges as:

– rehabilitation and strengthening of biological and ecological stability of oak as the main forest-forming species;

–restoration and enhancement of the sustainability of oak stands as the main component of the plant community;

–restoration and enhancement of the sustainability of all oak forest biocoenosis as the defining element of the respective forest ecosystems.

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