Improving the Geoecological Monitoring System of Forestry

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Abstract

The issue of understanding large-scale biospheric processes is closely related to the problem of preserving and restoring forest resources, which are among the key factors ensuring the stability of the continental biosphere. This article highlights the programmatic principles of geosystem monitoring of forests in the context of modern climate change. The foundation of the geosystem monitoring strategy is based on a predictive topo-ecological concept. As the first step toward understanding the local mechanisms of global changes, the methodological construction of "empirical imitation of regional bioclimatic trends at the local level of ecosystems" is proposed. It is considered expedient to conduct complex and multi-directional geoecological monitoring within biogeographic ecotones, since they exhibit high sensitivity to climate fluctuations.

Keywords: Global climate change, forest ecosystems, geosystem monitoring, predictive topo-ecological concept, discrete empirical-statistical models, biogeographic ecotones, landscape-ecological forecasting.

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1. Introduction

At present, under the conditions of ongoing and anticipated global climate change caused by anthropogenic increases in atmospheric CO_2 and other greenhouse gases, a considerable number of ecological forecasts have been developed at both global and regional levels [1–3 and others]. The majority of these studies are global forecasts aimed at assessing the future state of the biosphere as an integrated planetary system. They are based on the analysis of the most general landscape-geophysical relationships and are developed at very large spatial scales.

In such forecasts, two main approaches are generally applied: Computational (theoretical) models, particularly forecasting methods based on General Circulation Models (GCMs) of the atmosphere; Paleogeographic scenarios constructed primarily on the basis of the Holocene Climatic Optimum and the Mikulino

Interglacial period conditions [1]. However, these paleoanalogues are often insufficiently justified and excessively simplified when used as analogues for future landscape-ecological conditions. The situation is considerably more complex with regard to regional ecological forecasting. In many cases, regional forecasts are developed by applying fragments of global forecasting scenarios to subcontinental regions or individual countries. Consequently, they often possess low spatial resolution that is not fully compatible with regional scales. As a result, ecological forecasts are generally limited to assessing shifts in natural zone boundaries, changes in the distribution ranges of certain forest-forming tree species, or variations in agricultural crop productivity [2]. The primary source of such forecasts is paleogeographic reconstructions based on palynological data, which are derived from a very sparse network of observation points. Even assuming their reliability, such reconstructions are unable to reveal the regional and local diversity of future ecological conditions. This limitation is explained by the lack of empirical data and the absence of forecasting methodologies consistent with the natural-territorial organization at the regional level. It should be emphasized that the ecological consequences of climate change at regional and local levels of the biosphere manifest themselves more rapidly than at the global scale and may, in some cases, reach catastrophic proportions [3]. Therefore, although the violation of the Le Chatelier principle caused by anthropogenic increases in atmospheric CO_2 concentrations may not critically disrupt the biosphere as a whole, it can lead to severe disturbances in its individual components. It is well known that global biospheric processes originate within specific regions. Their discrete nature generates significant spatial and temporal heterogeneity in the overall pattern of global environmental change. Within the well-known hierarchical triad of geo(eco)systems—planetary, regional, and local (topological) levels—the regional units of the biosphere exhibit the greatest individuality and structural complexity. This is determined by the uneven interaction between external climatic factors and the Earth's surface within each region. As a result, geographical fields develop strongly expressed internal regional contrasts, whereas interregional continuity appears weak or may be absent altogether. The methodological difficulties associated with transitioning from global to regional forecasting arise precisely from this circumstance. At the regional level, the number of input variables determining the hydrothermal regime of geo(eco)systems increases dramatically. Consequently, regional forecasting remains insufficiently developed. This situation necessitates the development of specialized methodologies for regional ecological forecasting. The method of regional landscape-ecological forecasting, as a component of the paleoforecasting concept, may serve as a promising example of such an approach. Monitoring Complexity and Geoecological Monitoring of Forest Ecosystems

The complexity of monitoring is primarily associated with the multifactorial nature of climate system impacts and the multifactorial responses of landscape structures of different hierarchical levels and their components to the same global and regional climate signals. Consequently, a high degree of uncertainty remains regarding the impacts of global changes themselves [6], as well as the frequent "adaptation deficit" of forest ecosystems to these changes. This brings to the forefront the problem of the hierarchy of ecosystem response scales and their spatial integration. As territories designated for monitoring spontaneous processes in the biosphere, including global anthropogenic changes, biosphere reserves characterize not only the zonal and regional background conditions of a given territory but also the typical diversity of local deviations from this background, which may imitate the background characteristics of other regions, often located at considerable distances. The diversity of biogeocenotic structures within the regional ecosystem under study should correspond to the diversity of their responses to global changes. This requires a comprehensive multidimensional analysis of both the structure and functioning of forest ecosystems. One of the most promising directions for further research in regional dynamic ecology under conditions of global climate change is the implementation of a series of experiments aimed at studying local response mechanisms to global and regional hydroclimatic signals. Such studies would make it possible to identify systems of transmission and transformation functions within landscape relationships. The ecotone spectrum of natural zones covering the main watershed of the Volga Basin represents a highly suitable model territory for conducting such experiments. A rational system of geoecological monitoring can only be developed on the basis of existing achievements in the study and management of environmental conditions [8]. Within working approaches to the development of the geoecological monitoring concept, it is possible to define strategies for the priority advancement of at least three interrelated tasks. First, it is necessary to identify and establish the fundamental mechanisms governing the territorial organization and functioning of forest ecosystems. These mechanisms may be considered intermediary links in the local distribution and transformation of global and regional climate signals. Second, it is necessary to determine the pathways and transformation mechanisms through which these signals are transmitted across systems of intercomponent and intercomplex landscape relationships, accompanied by the construction of corresponding empirical models. Third, it is essential to identify the mosaic of local responses to global impacts through predictive experiments using landscape relationship models under specified scenarios of anticipated global climate change. The concept entitled "Ecological and Socio-Economic Threats of Forest Degradation in Uzbekistan and Ways to Prevent Them", developed within the National Program for Priority Directions in Forest Science Development [11], envisages the following priority tasks: Development of monitoring methods and technologies for assessing the resource potential, ecological condition, biodiversity, and functions of forests;

Development of forecasting models for forests under the combined influence of natural and anthropogenic factors, including climate change [12]. Among the adaptation measures relevant to forestry, particular emphasis should be placed on: Conservation of existing forests and modernization of technologies for forest restoration on degraded lands; Establishment of adaptive forest ecosystems as a new category of protective forests.

2. Conclusion

The strategic objective of forest cover monitoring research is to assess and ensure the stability and sustainability of forest ecosystems under the conditions of contemporary global warming.

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