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The Methodological Principles of Setting Up Soil Monitoring in Protected Areas

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Abstract. The article discusses the methodology of organizing soil monitoring in the territory of Eastern Fennoscandia. The history of developing monitoring studies of soils is presented. The main stages of monitoring are shown. Soil monitoring requires an adequate selection of indicators to match the type of impact and the mission of the monitoring. The importance of complex studies in soil monitoring is shown. It is noted that it is possible to change the monitoring objects in response to the increase in anthropogenic impact. The need for international cooperation in monitoring the natural environment in connection with global climate change is discussed. Continuous and consistent observations based on integrated research are what enable a reliable assessment of the current state of the natural environment in protected areas. This particularly applies to soil monitoring in valuable UNESCO heritage sites (e.g., rock art – White Sea and Lake Onega petroglyphs).

Keywords: natural environment, protected areas, soil monitoring

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1. Introduction

Natural environment monitoring commenced in the mid-20th century [6], and continues evolving [2,7] to a fundamentally new level. High human pressure on forest ecosystems has necessitated more activate monitoring surveys and further elaboration of the general theory of nature protection, revealed the need for assessing the qualitative and quantitative parameters of the state of natural and disturbed ecosystems [2,6,7]. As human impacts on forest ecosystems have become more diverse, the actions required also need diversification, including search for new indicators of the state of the environment and new objects to be monitored, improvement of research approaches and methods, and designing totally novel prognostic models for forest ecosystem monitoring. Monitoring results are of high theoretical scientific value as they form the information background for conservation planning and predicting potential changes in the natural environment.

2. Methods and Equipment

2.1. Methods

Soil monitoring, as part of environmental monitoring, rests on the following basic principles:

- Monitoring is carried out within a predefined area.

- The object of monitoring is of high scientific/economic significance.

- Soil monitoring is performed at preset time intervals. E.g., the microbial community of undisturbed soils is analyzed biennially, while the soil humus status – once in 5-7 years. The monitoring frequency under substantial human impact should be higher.

- Information is gathered from diverse sources, with a primary role of permanent observation sites (POS) and permanent sampling plots (PSP); a valuable source is remote sensing data;

- Hardware and software are used for building databases, including the use of GIS technology to process and visualize geospatial information.

Soil monitoring requires an adequate selection of indicators to match the type of impact and the mission of the monitoring. E.g., analysis of morphological properties is a good way to trace the "post-fire past" of the soils: buried horizons or impurities indicate the community was affected by a fire. The acid-alkaline properties of soils are among the key indicators in monitoring. Human impact can cause a reduction or rise in soil acidity, thus influencing the migration capacity of nutrients, the microbial activity, and the productivity of tree stands. A more objective assessment of the natural environment also requires the investigation of soil texture, which is a significant determinant of soil-formation processes and the forest site quality. It influences the processes of matter migration, accumulation, and transformation, as well as the physical, physicomechanical and hydrological properties of soils, and their microbial characteristics. The microorganism adsorption capacity of soil particles is subject to change, due to which the synthesis/degradation of organic compounds is disrupted. Other important variables used in monitoring are carbon and nitrogen contents. These elements are known to play a major role in shaping the humus status of soils and to be the key to optimal functioning of the plant community. The composition and properties of humus, its distribution over the soil profile depend on the pedogenic processes and reflect the state of the organic matter formed under the given conditions. This parameter can provide valuable information for long-term soil monitoring. The content of macro- and microelements is another important indicator of the processes happening in the soil and is actively

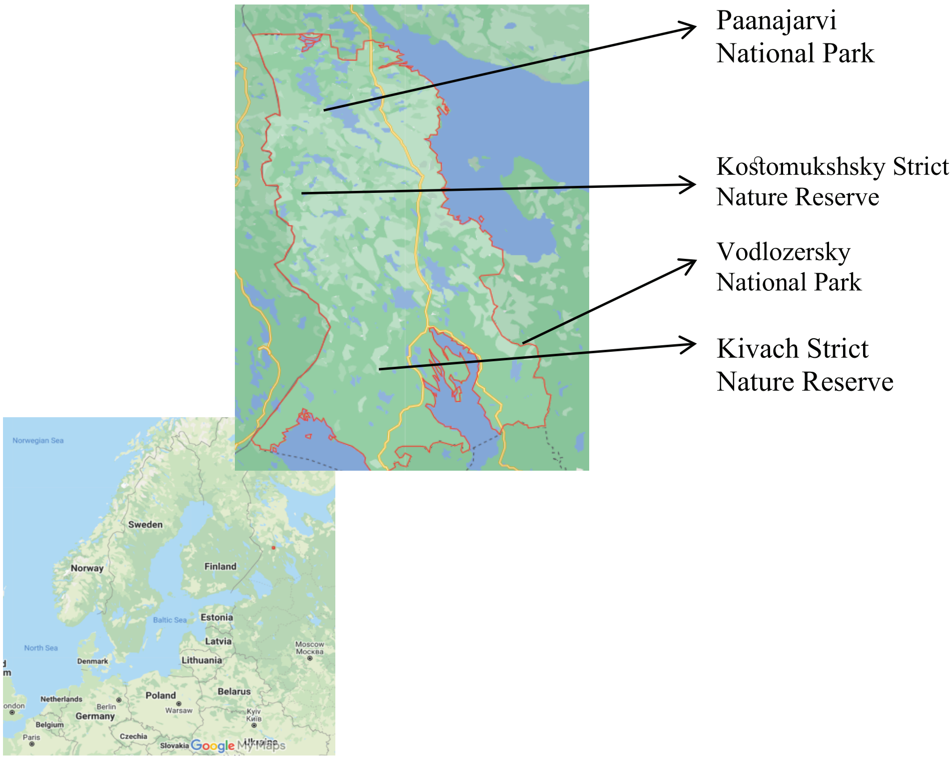

Figure 1: Monitoring objects in Karelia.

used in soil monitoring. Proven sensitive indicators are characteristics of soil microbial activity, determined both in laboratory experiments and in situ. These characteristics are used to map the spatio-temperal patterns in the activity of the microbial community and to identify changes in the habitat in the context of ecosystem succession.

The soil parameters mentioned above provide an adequate insight into the current state of the natural environment. Yet, this listing can be and continues to be expanded to meet the need for early identification of changes in edaphic conditions and for timely implementation of conservation actions [3]. The said indicators can also be used in the making of zonal models of boreal ecosystem dynamics. Advancements in geographic information technology and large-scale soil mapping support the expediency of continuing soil inventory activities, research into soil genesis, further systematization of knowledge on the soil cover structure, and elaboration of the soil classification. In the past 30 years, a network of sample plots for regular soil monitoring has been established in protected areas of Karelia (Fig.1).

The taxonomic position of the soils was determined according to the new Russian soil classification system [5, 8] and the World Reference Base [9]. Soil samples were taken from genetic horizons. We determined particle-size distribution according to Kachinskii, pH by potentiometry, the organic carbon content according to Tyurin, the total nitrogen content according to Kjeldahl, the total (hydrolytic) acidity and the sum of exchangeable bases according to Kappen using routine analytical procedures [1].

3. Results and Discussion

Regular environmental monitoring has been underway in Karelia since the early 1990s. Importantly, it is organized and implemented relying on a solid scientific basis, in conformance with international criteria, national standards, and various guidelines of relevance for the tasks. The research started in the context of a growing human impact on forest ecosystems, which required the development of criteria for quality assessment of the natural environment. Foundation of quite a number of large protected areas (Kostomukshsky Strict Nature Reserve, Kalevalsky and Vodlozersky National Parks, etc.) has resolved the problem of finding and maintaining reference background sites: soils in undisturbed forest ecosystems exemplify the quality of the natural environment in vast areas [4]. Also, the Kamalahti integrated monitoring site was established in northern taiga – the first international site for implementation of a project for the study of the natural environment of East Fennoscandian north-boreal forests. Unification of soil research methods was later significantly promoted by the ICP Forest program.

4. Conclusion

To conclude, a soil monitoring system employing international methodology has been created and operates in Northwest Russia (in Eastern Fennoscandia), and extensive factual material on soils of the region has been amassed. Yet, the tasks remain to further improve the existing research methods and tools and to produce new ones, to refine the diagnostic scales for the carrying capacity of the natural environment, to determine the natural background concentration of pollutants, to identify the adaptive zones of the biota, etc. Undoubtedly, continuous and consistent observations based on integrated research is what enables a reliable assessment of both the current state of the natural environment in protected areas and the potential changes due to global climate trends. This applies also to soil monitoring in especially valuable UNESCO heritage sites (rock art – White Sea and Lake Onega petroglyphs).

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