Application of geographic information systems for environmental monitoring on the territory of the forest sanitary zone of Novopolotsk, Belarus

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Abstract. This current research discusses the possibility to use geographic information technology to provide dendrochronological method of environmental monitoring with an efficient tool for spatial data analysis in order to develop an efficient network of environmental monitoring based on tree ring research within sanitary protective zone of Novopolotsk city, Belarus. In these studies emphasis is put on a landscape approach in analysing living conditions of trees.

1. Introduction

In 1980 dendrochronological research was initiated at the Department of Geodesy and Cadastres of Polotsk State University on the territory of the forest sanitary protective zone of Novopolotsk city, Belarus. The emphasize is put on monitoring the influence of natural and technogenic factors on the environment [1] using dendrochronological method, which studies the tree ring structures and their dynamic. The analysis of features recorded in tree rings have proven to be efficient to extract information about past events [5],[6] and to predict their future occurrence. The network of sample areas over the forest sanitary protective zone of Novopolotsk is part of a network of sample areas of dendrochronological monitoring over Belarus.
Nowadays the task of environmental projects carried out at the Department of Geodesy and Cadastres within the state program "Radiation and anthropoecology" is to develop a database of tree ring chronologies representing different living conditions and influence of natural and anthropogenic factors.

Living conditions (edaphic, orographic factors etc) as well as climatic factors (temperature, precipitation) etc significantly influence the radial growth of trees. Therefore, it is not possible to estimate the state of forest ecosystems using dendrochronological method without understanding the nature of the influence of natural and anthropogenic factors on forming the tree ring structure under different living conditions.
Geographic information systems (GIS) are a tool designed to capture, store, manipulate, analyze and visualize the different sets of georeferenced data that are required to support accurate modeling of environmental processes [4], and to provide dendro-

chronologybased environmental monitoring with the analysis of spatially distributed data.

2. Background

2. 1. Study Area

Novopolotsk is one of the largest industrial centres in Belarus and is located in the basin of the Western Dvina in the north of Belarus. The amount of atmospheric fall-outs from stationary sources in Novopolotsk city is the highest in Belarus. At present it is higher than 50 000 tons a year.

Industrial and residential parts of Novopolotsk are separated from each other by a green sanitary protective zone, which is 4 - 5 km wide and its area is approximately 5 000 ha. The study area is shown in figure 1 below. The forest of the sanitary-protective zone consists mainly of conifers of natural origin, which are replaced by deciduous trees near industrial enterprises. The forest sanitary protective zone acts as biological filter, which absorbs atmospheric pollutants spreading from the industrial

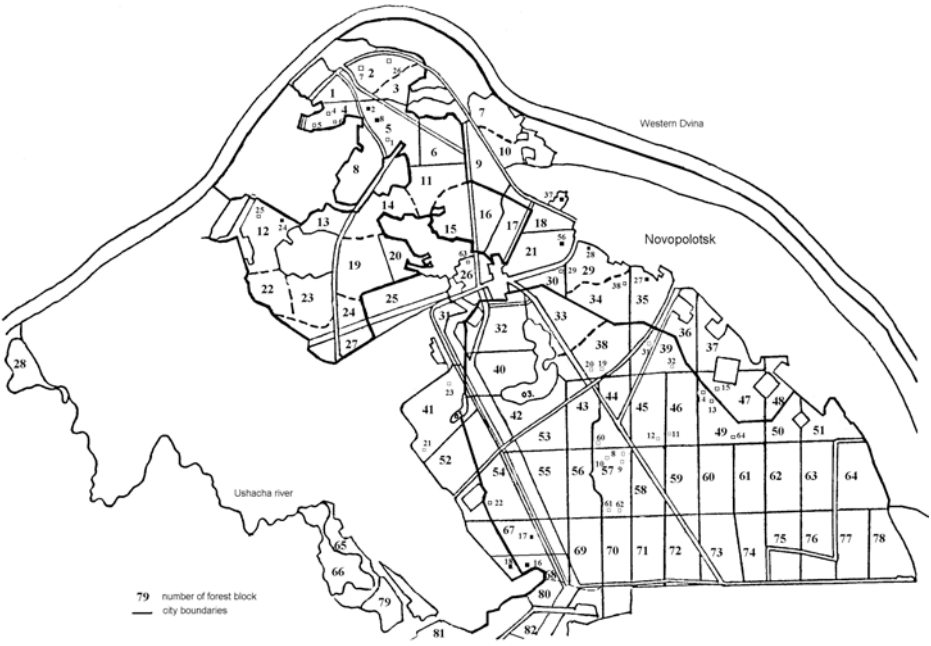

Fig. 1. Scheme of forest sanitary protective zone of Novopolotsk city

part of the city over residential areas and reduces their concentration in the residential part of the city.
On the other hand, trees of the sanitary protective zone act as natural indicators of the state of the environment. The sanitary-protective zone of enterprises of Novopolotsk city is consists of trees approximately hundred years old, and this allows applying the dendrochronological method of environmental monitoring. The network of continual dendrochronological studies consists of approximately 40 sample areas and profiles located in diverse living conditions.

2.2. Use of Dendrochronological Method of Environmental Monitoring.

Radial increment of tree stands serves as an integral characteristic of phytocenosis's production, describes their viability, reflects cyclic recurrence of natural phenomena, allows to reveal the influence of technogenic factors on environment to understand the reasons of forest degradation, and to reconstruct past climatic conditions. Studies of tree ring structure of the afforestation affected by aerotechnogenic, irrigational and drain, recreational, pyrogenic influences etc allow to estimate the state of the forest stands, steadiness of their functioning and to recognize the dynamics of growing process.
The width of tree rings is an integrated parameter. Local conditions as well as climatic factors have large influence on tree growth. In order to derive the necessary information from tree ring rhythms, detailed investigation of the relationship of different environmental factors is required. By measuring and analyzing tree ring rhythms it is possible to determine the cyclic influence of natural factor on the environment, to derive a technogenic signal.
In order to extract the technogenic signal from dendrochronologies developed for trees affected by any of technogenic factor one needs to compare radial growth dynamics with those obtained for analogue forest stands of national and reserve parks, or other placed, where influence of technogenic factor on environment is considered insignificant. Comparison of tree ring chronologies shows the magnitude of influence of certain technogenic factor.
In order to analyze living conditions for the purpose of dendrochronological studies the term landscape is used.
Landscape is a genetically homogeneous area, characterized by similar relief, soil, climate, hydrology, living organisms and human impacts. Relief forms the basis of landscape. Among the main relief types in the north of Belarus are those having glacier origin. Main characteristics of north-Belarusian landscapes are small sizes, high diversity of landscapes, large number of lakes, hollows, complexity and diversity of top-soil, conifers.
Landscape is understood as the totality of interconnections between components (it forms vertical structure) and spatial units (horizontal structure). Geological structure, relief, hydrology, soil, lower atmosphere layer, vegetation etc are components of vertical structure. Landscape can be represented by simpler morphological units, e.g. tract or phase, which are elements of horizontal structure and more used when dealing with quite small areas such as study area. Integration of GIS dendrochronology and

landscape approach of environmental data and wider use of their possibilities helps to widen the use of each of these three components of environmental studies.

3. GIS provision for dendrochronologybased environmental studies.

Use of GIS for dendrochronological research can bring a number of advantages [2]. It allows us to query and fully investigate temporal and spatial data, to deepen our view of the problem and extend our knowledge about the spatial distribution of environmental parameters, to determine interconnection between them etc.
As a basis for development of GIS for provision of dendrochronologybased environmental monitoring for study area topographic map of scale 1:10 000 is used. For needs of specific tasks maps of larger or smaller scale can be used.
Remote sensing data (satellite and airborne data of 1987 and 2004), thematic cartographic material such as geological, geomorphological, soil, soil acidity, graphical and text material of forest husbandry, databases of regular observations such as climatic, soil-hydrological, agrochemical, measurements of tree ring structures and other biometrical measurements are used as initial data.
Cartographic material has different scales. Most of thematic maps are made in the scale of 1:25 000. Maps of forest husbandry are in a scale of 1:10 000.
Input of data to a GIS involves several main stages. For the manual input data there are following stages: entering the spatial data, entering the attribute data, spatial and attribute data verification and editing, and, where necessary, linking the spatial to the attribute data [3].
Most of data needed for current task were in analogous form. Maps and schemes are scanned. Raster maps are scaled, and digitized (vectorized) if it is needed. For our task interactive method of vectorization is used.

In the current stage of the work the following issues benefit from integration of GIS and dendrochronology method:

- analysis of thematic information stored in different data layers in order to characterize existing network of tree ring research and representation of diversity of living conditions within the study area and to suggest places to locate sample areas, if necessary;
- determination the changes in radial growth between different periods of time and to analyze spatial characteristics of territories of radial growth dynamic change;
- development of generalized chronologies (master-chronologies) with the assistance of analysis of environmental parameters performed with the help of GIS;
- ensuring of possibilities of environmental prediction, imitating modeling of processes, complex monitoring of environmental parameters using landscape approach;
- computing the magnitude of technogenic load on environment;
- determining the dynamic of flooded areas;
- determining areas under forest fire risk (analyzing slope, aspect, amount of forest fires);
- visualizing the results of dendrochronological research;

- studying other possibilities of joint use of GIS and dendrochronological methods for the purpose of environmental monitoring.

4. Concluding remarks and future work

Studying of possibility of integration of GIS and dendrochronological methods for studying environmental situation in heavy polluted industrial city we see that GIS has huge potential to be used for dendrochronologybased environmental monitoring. Most of suppositions are made so far analytically and just on the basis of preliminary tests for some areas of interests.
Mentioned work could be regarded as preliminary stage of development of fully functioning integrated system of environmental monitoring based of dendrochronologycal methods and GIS technology.

Future work on this project will be directed to:
- gathering of full set of required for project data for the whole territory of forest sanitary protective zone of Novopolotsk city;
- implantation of recently acquired remote sensing data (airborne and satellite images);
- development of algorithms of temporal and spatial modeling and predicting of redial growth of tree and environment state for the set of environmental parameters including different types of technogenic influence;
- spatial interpretation of radial tree growth prediction in GIS.

5. References

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