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Dendroindication of synchronous trends in productivity (middle-taiga of Arkhangelsk region, Russia)

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Introduction

Interaction of landscape components, i.e. relief and rock, local climate, water, soils and vegetation, determines the structure and dynamics of the landscapes.

Principles of structure creation are best understood through the study of their functioning, i.e. the process of component interaction. The structure can be looked at in terms of different hierarchical levels.

Evolution and external factors of landscape dynamics are equally important aspects understood through the study of landscape functioning.

Spatial-temporal synchronous processes in landscapes is one of the central issues in the modern studies of landscape functioning. One approach to understanding the processes is searching for natural registering means that reflect both variability of external and internal landscape conditions and spatial distribution of landscape functioning processes. Tree-rings found in abundance in most boreal zone landscapes are a good example of such means.

Therefore, we suggest the dendrochronological method, which allows describing biological productivity, the key indicator of variability. This method can be used as the main tool in studying the in-centennial rhythms of functioning of local-scale landscapes.

We rely on theory and methods of both landscape studies and dendrochronology. Accordingly, we apply both geographical and dendrochronological scientific principles. Hence, we suggest the name “Landscape dendrochronology” to define this new area in physical geography (Beliakov, 2003).

Materials and Methods

The materials were collected along the line of local landscape transect located in the middle-taiga subzone in the South of the Arkhangelsk region, Russia. The study region is characterized by temperate climate (no growth-limiting factor), young (under 100 years old) forests, and sizeable anthropogenic influence (timber industry). The sampling process was standard as described in the literature (Josza, 1988). It included getting cores by increment borer and stem disks by chain saw.

Nearly 300 increment cores and stem disks of *Pinus sylvestris* L*., Picea abies* L. (Karst) and *Picea obovata* Ledeb. were collected along the line of an 8125 m transect. The transect passes through a diverse range of sites: different types of forest, oligotrophic and mesotrophic bogs, valleys of small rivers and creeks. The transect is representative of the spatial structure of the region.

The measurements followed the standard procedure: cores and stem disks were scanned and the tree-rings were digitized by an image editor; the ring-widths were calculated semi-automatically. All the samples collected from one site were crossdated and verified to exclude the false rings and find the missing rings. The data that could not be crossdated were excluded from further computation of site chronologies. The age-related trends in each series were minimized by applying two statistical methods: cubic spline (length of wave - 32 years) with further site chronology computation by a biweight robust mean estimation using ARSTAN program developed by Cook (Cook, 1985), and five-year moving averages smoothing with chronology computation using arithmetic mean value function.

The correlations and similarities (Gleichläufigkeit) (Eckstein, Bauch, 1969) between tree-ring chronologies of each site were then calculated. The same coefficients were also calculated separately for series covering periods 1960-1970, 1970-1980, 1980-1990, 1990-2000 to evaluate short trends in productivity.

Results

Analysis of correlation between tree-ring chronologies of landscapes showed their synchronous reaction to external factors.

The five-year moving averages smoothing method resulted in average correlation coefficient of 0.83 for chronology series. The 0.97 maximum correlation coefficient was observed for two chronologies of neighboring forest landscapes on the local watershed. Two border zones of bogs (local ecotones) also react quite synchronously, but correlation between them and other landscapes varies between 0.3 and 0.8.

High correlations were also observed in series processed with the ARSTAN program.

Similarity (Gleichläufigheit) varies greatly. At different time periods the trees demonstrated great variability in productivity synchrony, although they were clustered relatively close to one another. The most synchronous were the sites on level drained watersheds with zonal vegetation and soils. Since 1970s the productivity in different sites has been getting more and more asynchronous. Least synchrony was observed in droughty and warm 1990s. Nevertheless, in 1980s and 1990s the increments at a wide oligotrophic bog and a wooded hollow were quite synchronous. Thus, we considered them functionally related.

The process of functioning (productivity) studied by applying the dendrochronological method allowed us to identify different geographical systems. For instance, the 1970s synchronous increments in landscapes of the valley of the main river of the region, Zayachya and its local inflows clearly showed the domination of basin-type landscape organization. In 1990s wide oligotrophic bogs and their border zones (local ecotones) and even a few landscapes located close to them were quite synchronous in productivity showing the nuclear type (Reteyum, 1988) of landscape organization (i.e. the central part of the bog being the nucleus). The influence of the nucleus on the border systems was found to be loosening as the distance increases, providing a great example of the famous “decrement law”.

At other time periods these types of landscape organization at the same sites were significantly less clearly pronounced. Application of the dendrochronological method allowed us to find out the periods of stronger spatial relationships. Visibility of the specific types of landscape organizations was found to depend on changes in global and local climate.

Traditionally, the Russian school would expect the actual landscape borders to match geomorphological borders derived based on landforms and their genesis. Our study showed that the borders of geographical systems defined by productivity do not consistently demonstrate such match. Therefore we added new evidence supporting the argument of continuity of landscapes.

Conclusions

Global climatic factors affecting all landscapes of the transect at same times are the basics of spatial-temporal synchrony. Each in-centennial rhythm of increments (productivity) is characterized by its own level of synchrony. In young forest communities, the discovered asynchrony is a product of community-specific trends. It was also caused by anthropogenic factors and the overall absence of common limiting factor. We identified three mechanisms forming landscape structure organization: “geostationary” (related to stable site-specific geomorphologic base), “biocircular” (continuous rhythmic activity of vegetation ignoring genesis-based borders), and “geocircular” (matter and energy transfer, e.g. processes in basin-type and nuclear-type geographical systems), that place our findings conceptually close to those outlined by Solntsev (1981, 2001) in his “geostructure” theory.

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