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Possibilities for the forecast of tree radial growth and agricultural crop productivity

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The dependence of radial growth of trees on various factors and its application are discussed. One of the possibilities of the application is the prognosis of productivity tendencies. The reliability of agricultural crops' prognosis is closely related with the conditions of agrocoenoses and tree growth. Best results are achieved when agrocoenoses and trees grow in soils of similar mechanical composition and hydrological regime.

Key words: tree radial growth, agrocoenoses, relations, prognosis, Lithuania

INTRODUCTION

The information based on investigation of tree rings (width, density, chemical composition) is more and more often used in dendroclimatology and dendrochronology (Битвинскас, 1974), astrophysics (Дергачев, Векслер, 1991), discussing forest monitoring and the anthropogenic impact on vegetation (Юкнис, 1987; 1990) etc.

Using the regularities of radial growth of trees and its dependence on climatic factors, not only former climate has been reconstructed but also the forecast methods are being investigated (Yadav et al., 1991; Kairiukstis, Stravinskiene, 1987; Кайрюкштис, Дубинскайте, 1986).

Methods used in dendrochronology and dendroclimatology are more and more widely applied in detecting a relation of the productivity of various agricultural crops to the dynamics of tree rings (Bitvinskas et al., 1994; Битвинскас, Брукштус, 1990; Кайрайтис, 1990; Жирина, 1987) and using these links for the forecast of productivity.

The purpose of this paper is to explore the common signals of various factors for agricultural crop productivity as well as radial growth of trees. In most cases literature sources were used.

MATERIALS AND METHODS

The methods and results have been widely discussed in an article by L. Zhirina, and for comparison we will use the results obtained at the DCh laboratory.

The staff of the former Dendrochronological Laboratory has collected rich dendrochronological research data in Lithuania and abroad. The main species studied are Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) Karst.) and English oak (*Quercus robur* L.). Detailed methods of the accumulation and processing of dendrochronological data have been described in the previous works of the laboratory researchers (Bitvinskas et al., 1994; Kairaitis, Karpavicius, 1996; Karpavicius et al., 1996; Битвинскас, 1974; Карпавичюс, 1984).

For tree ring analysis, no less than 10 increment cores one from each tree were taken at breast height from each experimental plot by using an increment borer. Tree rings were dated and measured using a microscope. Pine and spruce rings were measured within 0.05 mm and oak rings 0.1 mm accuracy.

Earlywood and latewood increment was measured separately, and mean ring width chronologies of each species from all experimental plots were constructed. For elimination of age curve, indices were calculated on the basis of methods described by T. Bitvinskas (Битвинскас, 1974). Trying to obtain possibly reliable results concerning the indices of radial growth and annual dynamics of agricultural crop productivity, the data were recalculated per cent by dividing annual data of each agricultural crops by its long-term average and multiplying by 100. The obtained ring width series were used for the further analysis. In several experimental plots soil analysis was performed. Attention was focused on the mechanical composition of soil and the level of groundwater (Kairaitis, Karpavièius, 1996).

To study a link between radial growth and agricultural crop productivity, data on radial growth from more than 20 experimental plots located 5 to 50 km from Kaunas (54°55' N, 23°56' E) were used, and the data on agricultural crop productivity were collected. Some research data for the period 1970–1991 from Department of Agriculture of the Univer-

sity of Agriculture of Lithuania were used (Bitvinskas et al., 1994). Data on agricultural crop productivity obtained by author by many-year observations in Kaunas district in 1965–1983 were also used. Links between radial growth of trees and bioproductivity of agrocoenoses were estimated using the coefficients of correlation. To evaluate the reliability of the coefficients of correlation, Student's criterion was used.

RESULTS AND DISCUSSION

The coefficients of correlation (*r*) between the radial growth of pine (*Pinus sylvestris*) and spruce (*Picea abies*) and agricultural crop productivity showed a different relationship (Bitvinskas et al., 1994) (Table 1).

The highest coefficients of correlation between the radial growth of pine and clover productivity was with earlywood $r = +0.41$, latewood $r = +0.42$ and with annual increment $r = +0.48$, reaching with spruce earlywood $r = +0.30$, latewood $r = +0.42$ and with annual increment $r = +0.35$. A slightly lower coefficient of correlation was obtained between the radial growth of pine and the annual data on potato productivity.

Inverse coefficients of correlation between the radial growth of spruce and the harvest of potatoes were established: with earlywood $r = -0.52$, with latewood $r = -0.28$ and with annual increment $r = -0.52$. Similar data were obtained for the phytomass productivity of maize and the radial growth dynamics of spruce, whereas the correlation of the radial growth of pine and spruce with the harvest of wheat, rye, barley and oats was considerably low, rarely reaching 0.30 (Bitvinskas et al., 1994).

In the years of extreme climatic conditions, the dynamics of tree radial growth and agricultural crop productivity coincide well enough. After cold winters of 1979–1980, decreased not only the earlywood increment of pines, but also the productivity of wheat and rye (Fig. 1).

Similar results with other agricultural crops were also presented by T. Bitvinskas and V. Brukštus

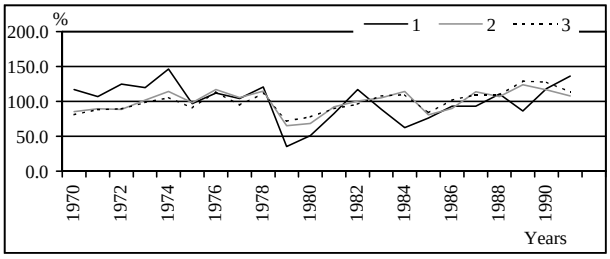

Fig. 1. Dynamics of annual radial increment (earlywood) of pines from the Panemunë Park (1) and productivity of wheat (2) and rye (3)
Pav. 1. Pušø iš Panemunës parko ankstyvosios medienos prieaugio (1) ir kvieèiø (2) bei rugiø, (3) derlingumo dinamika

(Битвинскас, Брукштус, 1990). Relationships among the productivity of different agrocoenoses and tree radial growth dynamics depend also on other factors. One of them is the time of sowing and ripening. The requirements for soil, light, and conditions of hydrological regime differ too. It is also important whether it is a perennial or annual cultured plant. The correlation is more stable with perennial cultured plants, because they have been longer exposed to the same climatic conditions. Different reasons should be mentioned there. However, in spite of great differences, part of fairly high coefficients of correlation indicate that they are not accidental. It is proven by the coefficients of correlation with latewood growth. In most cases they are not reliable, because often the beginning of latewood growth coincides with the crops ripening and harvest periods.

As one can see from the discussion above, evaluation of the relationship between the productivity of cultured plants and the radial growth of trees is complicated. It is most important to define the criterion of evaluation of the basic relationship. One of the criteria is growing conditions. Other researchers are of the same opinion.

According to the data of J. Kairaitis (Кайрайтис, 1990), the correlation between radial growth of oaks growing on clay soil with the harvest of beet, which are typically cultivated on clay and loamy soils, was

Table 1. **Coefficients of correlation between radial growth of trees and productivity of agricultural crops**
1 lentelë. **Medþiø radialiojo prieaugio ir þemës ûkio augalø produktyvumo koreliacijos koeficientai**

Tree species	Wood part	Agricultural crop							
		Clover	Potatoes	Beet	Rye	Wheat	Maize	Oats	Barley
Pine	Early	0.41	0.30	–0.40	0.27	0.35	0.06	–0.05	0.27
	Late	0.42	0.01	–0.11	0.24	–0.04	0.01	–0.04	0.04
	Annual	0.48	0.28	0.16	–0.08	0.01	0.10	–0.04	0.02
Spruce	Early	0.30	–0.52	–0.11	0.09	0.22	–0.54	0.03	0.16
	Late	0.42	–0.28	0.28	0.10	0.22	–0.11	–0.07	0.12
	Annual	0.35	–0.52	–0.05	0.10	0.24	–0.50	0.26	0.16

0.58. The coefficients of correlation between the radial growth of oaks and the harvest of potatoes are lower, especially when the oaks grow in clay soil (r = 0.20).

Respective cycles are peculiar to the dynamics of tree radial increment. Recurrence of these cycles enables to prognosticate the increment reliably enough for some decades in advance. Using the methods proposed by L. Kairiûkðtis and I. Dubinskaitë (Кайрюкштис, Дубинскайте, 1986), the prognosis of radial increment the oldest pines growing of the Panemunë Park was developed (Fig. 2).

For evaluation of the prognosis, after nearly 20 years cores from trees of the same plot were taken again and the increment was measured (dotted line in Fig. 2).

As one can see in Fig. 2, the calculated prognosis reflects the long-term (5 and more years) tendencies of the radial increment well enough (r = 0.62). Using correlations between the biological productivity of a phytocoenosis and the radial increment of trees, it is possible to forecast not only the radial increment, but also the productivity tendencies of agricultural harvests.

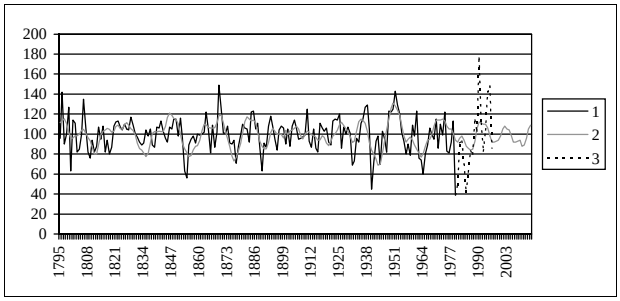

Fig. 2. Prognosis of the radial growth of pines in the Panemunë Park. 1 – radial growth used for prognosis (1795–1978); 2 – approximated radial growth (1795–1978) and prognosis for 1979–2014; 3 – actual radial growth data for 1979–1996

2 pav. Puðies radialiojo prieaugio prognozë Panemunës parke. 1 – radialusis prieaugis naudotas prognozei (1795–1978); 2 – aproksimuotas radialusis prieaugis (1795–1978) ir prognozë (1979–2014); 3 – faktiniai radialiojo prieaugio duomenys 1979–1996

CONCLUSIONS

Studies have revealed a rather close connection between the radial growth of trees and the productivity dynamics of agrocoenoses. It is possible to prognosticate the productivity of agricultural crops on the ground of radial growth regularities.

The similarities of the reaction of trees and agrocoenoses are highly influenced by the hydrological characteristics of soil. The greater the similarity of the soil hydrological conditions, the greater the similarity in their reaction to the impact of temperature and precipitation.

For a reliable prognosis, it is expedient to select trees and agrocoenoses growing in soils as close as possible by their mechanical composition and hydrological regime.

If there is no such possibility, it is expedient to use radial growth data of different tree species.

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References

1. Bitvinskas T., Stravinskienë V., Randomanskienë G. Koreliacinë aplinkos sàlygø (hidroterminiø rodikliø), medþiø radialinio prieaugio ir þemës ûkio kultûrø derliø analizë. *VDU KBS DKCh laboratorijos ataskaita uþ 1992–1994 metus*. Kaunas, 1994. P. 86–89.
2. Kairaitis J., Karpavicius J. Radial growth peculiarities of oak (*Quercus robur* L.) in Lithuania. *Ecology*. 1996. N 4. P. 12–19.
3. Kairiukstis L., Stravinskiene V. Dendrochronologies for moist forests of the Lithuanian SSR and their application for ecological forecasting. *Annales Academiae scientiarum Fennicae, Series A, III Geologica - Geographica*. 1987. Vol. 145. P. 119–135.
4. Karpavicius J., Yadav R., Kairaitis J. Radial growth responses of pine (*Pinus sylvestris* L.) and spruce (*Picea abies* (L.) Karst.) to climate and geohydrological factors. *Palaeobotanist*. 1996. Vol. 45. P. 148–151.
5. Yadav R. R., Nakutis E., Karpavichus J. Growth variability of Scots Pine in Kaunas region of Lithuania and approach towards its long-term predictability. *Arch. Nat. Schutz. Landsch. Forsch*. 1991. Vol. 31. P. 71–77.
6. Битвинскас Т. Дендроклиматические исследования. Ленинград, Гидрометеоиздат, 1974. 172 с.
7. Битвинскас Т. Т., Брукштус В. И. Радиальный прирост деревьев, экстремумы климата и урожаи сельскохозяйственных культур. *Тезисы докладов V всесоюзного совещания*. Свердловск, 1990. С. 20–21.
8. Дергачев В. А., Векслер В. С. Применение радиоуглеродного метода для изучения природной среды прошлого. Ленинград, 1991. 257 с.
9. Жирина Л. С. Возможность прогнозирования урожайности картофеля с помощью дендроклиматохронологических методов. *Временные и пространственные изменения климата и годичные кольца деревьев* (ред. Т. Т. Битвинскас). Каунас, 1987. № 2. С. 85–90.
10. Кайрайтис И. Ю. Связь радиального прироста дуба черешчатого и ели обыкновенной с урожаем некоторых сельскохозяйственных культур в окрестностях г. Каунаса. *Проблемы дендрохронологии и дендроклиматологии*. Свердловск, 1990. С. 74–75.
11. Кайрюкштис Л., Дубинскайте Й. Исследование ритмических колебаний радиального прироста деревьев для прогноза изменчивости климати-

ческих условий. *Дендрохронология и дендроклиматология*. Новосибирск: Наука, 1986. С. 161–174.
12. Карпавичюс И. А. Групповая изменчивость радиального прироста сосны в нормальных условиях местопроизрастания. *Временные и пространственные изменения климата и годичные кольца деревьев* (ред. Т. Т. Битвинскас). Каунас, 1984. С. 86–93.
13. Юкнис Р. Оценка антропогенных изменений роста деревьев и древостоев. *Дендроклиматохронологические методы в лесоведении и экологическом прогнозировании*. Иркутск, 1987. С. 168–173.
14. Юкнис Р. Дендрохронологические методы в системе мониторинга лесных экосистем. *Проблемы дендрохронологии и дендроклиматологии*. Свердловск, 1990. С. 170–171.

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MEDÞIØ RADIALIOJO PRIEAUGIO IR ÞEMËS ÛKIO AUGALØ PRODUKTYVUMO PROGNOZAVIMO GALIMYBËS

S a n t r a u k a

Aptariama informacija, gaunama tyrinëjant medþiø radialøjá prieaugá, ir jos panaudojimo galimybës. Viena jø – þemës ûkio augalø produktyvumo tendencijø prognozavimas. Nustatyta, kad tokiø prognoziø patikimumas yra glaudþiai susijæs su medþiø ir agrocenoziø augimo sàlygomis. Geriausi rezultatai gaunami, kai tyrimams naudojami panaðiomis sàlygomis, pagal dirvoþemio granuliometrinæ sudëtá ir hidrologiná reþimà, augusiø agrocenoziø ir medþiø prieaugio duomenys.

Raktaþodþiai: medþiø radialusis prieaugis, agrocenozës, priklausomybë, prognozë, Lietuva