Acta Biol. Univ. Daugavp. 11 (1) 2011
ISSN 1407 - 8953

CONIFEROUS FOREST ANNUAL GROWTH UNDER IMPACT OF BEAVER-MADE INUNDATIONS IN DOBELE FORESTRY, LATVIA

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Gackis M. 2011. Coniferous forest annual growth under impact of beaver-made inundations in Dobele forestry, Latvia. *Acta Biol. Universit. Daugavpil., 11 (1): 96-100.*

Increase of beaver *Castor fiber* L. population and species specific life-style in many areas cause damage to land drainage systems what affects forest stand annual increment formation. Therefore it is necessary to find average amount and direction of unvisible impact of inundation on forest stand growth.

Research made in central part of Latvia on october 2010 in drained pine *Pinus sylvestris* L. and spruce *Picea abies* L. stands which were be under impact of beaver-made inundation in nearby drainage system for at least 5 last years. Results show response reaction of 65 – 67 year old spruce and 81 – 85 year old pine stands. Investigated influenced and influence-free stand with the same inventarization parameters.

In the end of 5 year period of inundation influence the radial increment of both tree species stands decreased for about 40%. Beaver-made inundations create negative effect on pine and spruce annual growth, which in 5 year period can reach up to 5,5 m^3ha^{-1} in pine and 13 m^3ha^{-1} in spruce stands till 15 m distance from inundation side. After 15 m distance from inundation side the negative effect decreases and more sharply in pine than spruce stands (cumulative additional increment accordingly -2,5 and -9,5 m^3ha^{-1}).

Key words: annual growth, additional increment, coniferous forest, inundation, *Castor fiber* L.

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INTRODUCTION

More than 80 year ago in Latvia was started an introduction of once extincted animal- European beaver *Castor fiber* L. (Балодис 1990). Population and nature protection, local nature situation (forest coverage 52%) (SFS statistics 2011), dense net of natural and artificial watercourses (about 32% of all forest land are with drainage system) (SFS statistics 2011), global changes in fur commerce gives us now one of fastest growing animal population. This increase in combination with specific life-style of beaver (settlement place modifications and inundation formation) cause more and more damage to forest stand growth, land drainage system functionality and forest roads (Балодис 1990).

The influence of beaver-made inundation in nearby forest stands appears mainly as 1) dead wood formation (visible) and 2) changes in tree annual growth (unvisible) (Балодис 1990, Dams 1995, Rosell 2005). Visible damages are easy to calculate, but unvisible ones' mainly stay hidden from forest owner or manager. Therefore it is necessary to find average amount and direction of unvisible impact of inundation on forest stand growth. Previous researches show inundation negative effect on coniferous tree growth (Gackis 2009, 2010).

MATERIAL AND METHODS

Research was made in territory of Dobele forestry (central part of Latvia) on october 2010 in drained pine *Pinus sylvestris* L. and spruce *Picea abies* L. stands. These stands should be under impact of beaver-made inundation in nearby drainage system for at least 5 last years.

Data collected in total 10 research (with influence of inundation) stands - of 5 pine, of 5 spruce and 6 control (without influence of inundation) stands - of 3 pine, 3 of spruce. All stands selected with similar age, density, growing conditions and percentage of main tree species in stand. At each research stand taxation parameters and radial growth samples were collected on 3 straight, 50 m long and 1 m wide transects, which went perpendicular to damed drainage system. First transect started at beaver-made dam, second transect 25 m up-stream from dam, third transect 50 m up-stream from dam (Fig. 1). Radial increment samples taken with M. Presler's increment borer from last 16 annual rings from trees who were straight on transect lines. Taxation measurements done on transect line trees and closest 4 trees to calculate tree average diameter and stand density. Data in control stands were collected by the same transect layout in most typical part of stand.

Annual radial increment measured under LinTAB 5 measurement station microscope in resolution of ± 0,001 mm. Measured last 16 annual rings of each sample tree - last 6 rings (counting from bark) represent tree growth in inundation influence period, oldest 10 rings represent particular tree growth before inundation period. Annual radial increment is the base of all additional increment (tree response reaction) calculations for finding amount and direction of unvisible impact of inundation on forest stand growth.

Calculations of additional increments made by method of prof. I. Liepa (Liepa 1996) where the main result indicators are: 1) additional increment per unit of stand basal area and 2) cumulative additional increment per unit of stand basal area (both in m^3ha^{-1}). First indicator shows annual changes of tree growth under some environmental influence, second indicator shows sum of first indicators' values per defined period. Both indicators can be transformed into actual wood volume (m^3) per area multiplying it by basal area of proper stand. Additional increment is calculated from real and predicted radila increments, average tree diameter, particular stand density and constant coeficients of particular tree specie trunk form (Liepa 1996).

This method is created to calculate different kind of environmental impact on tree growth,

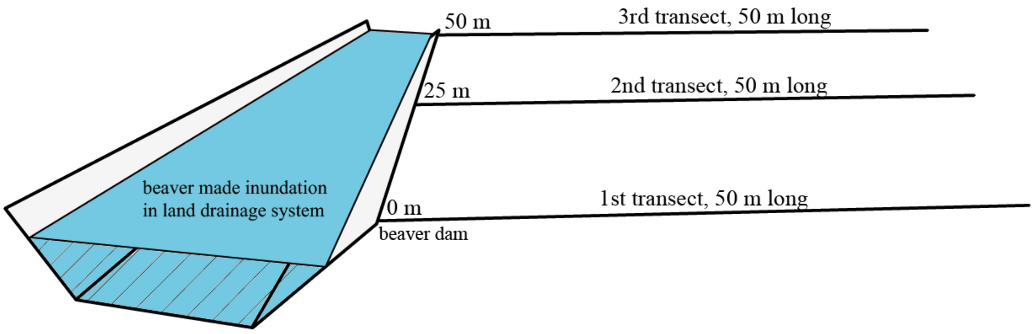

Fig. 1. Scheme of transect layout in influenced stand research.

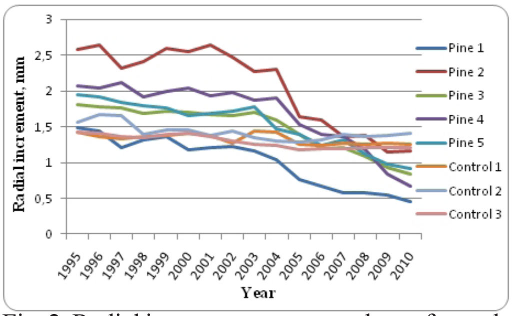

Fig. 2. Radial increment average values of sample pine stands.

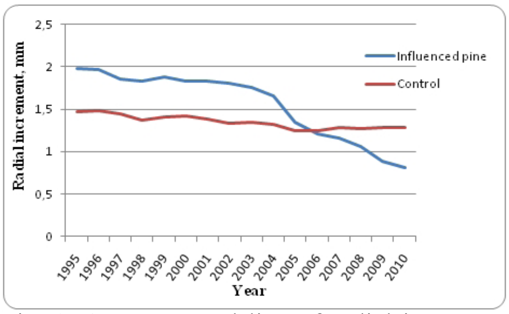

Fig. 3. Average trend line of radial increment average values of sample pine stands.

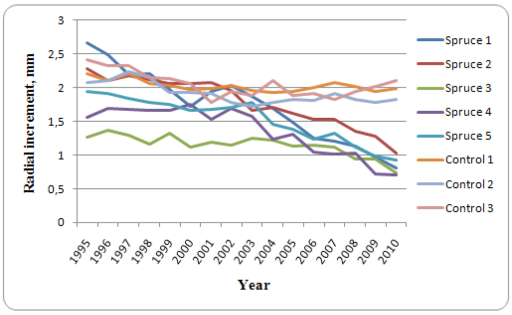

Fig. 4. Radial increment average values of sample spruce stands.

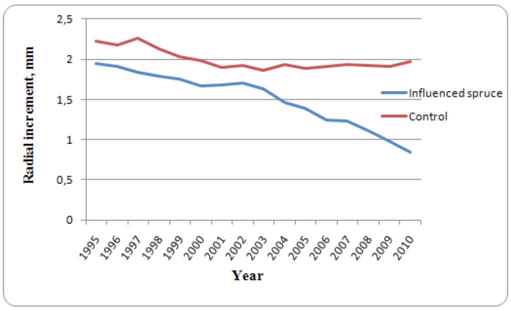

Fig. 5. Average trend line of radial increment average values of sample spruce stands.

both – positive and negative ones' (Liepa 1996). In this research it is predicted to find negative environmental impact.

RESULTS

All beaver-made inundations (water surface) at sampling stands didn't went over the edges of drainage system more than 3 m. This shows that inundation affect nearby forest stands mainly by rising groundwater level over tree root system.

In total annual increment measurements were collected: in pine stands from 129 influenced and 75 control trees, in spruce stands from 144 influenced and 71 control trees. Pine stands were 81 – 85 years old, but spruce stands 65 – 67 years old. Average values of annual increment of sampled pine stands are shown in Fig. 2 and Fig. 3 and average values of annual increment of sampled spruce stands are shown in Fig. 4 and Fig. 5.

In both cases (pine and spruce stands) visually comparing influenced and control stand radial increment trend lines it is visible that inundations are with negative influence on coniferous tree annual growth. The increment drop is quite slight to both tree species and make influence in last 5 – 6 years which is similar with inundation age. Previous studies shows quite fast reaction of trees on inundation formation (Дьяков 1975, Балодис 1990, Harkonen 1999, Gackis 2009).

To perform further calculations it was necessary to select adequate control trees from all control trees. It was done with correlation analysis relating average radial increment values to all control tree radial increments. The goal was to choose trees with most similar increment frequency. The forecasted increment (how trees would normally grow) of influenced stands was calculated on regression equation from retrospection period average values of adequate control and influenced stand tree radial increments. Forecasted increment is used to estimate the drop of radial increment and calculate additional increments. In Table 1 a summary of radial increment drop

Table 1. Radial increment drop (real from predicted) in influenced coniferous stands in 5 year period from start of inundation

Year	Radial increment decrease from predicted, %					
	Pine 1	Pine 2	Pine 3	Pine 4	Pine 5	Average
2006	17.8	21.0	7.5	18.4	8.2	14.6
2007	-22.5	-18.5	-4.0	-1.8	1.8	-9.0
2008	-16.2	-11.5	-10.8	-10.5	-10.8	-11.9
2009	-30.0	-33.6	-27.8	-40.5	-25.7	-31.5
2010	-41.7	-32.7	-34.6	-53.3	-30.4	-38.5
Year	**Radial increment decrease from predicted, %**					
	Spruce 1	**Spruce 2**	**Spruce 3**	**Spruce 4**	**Spruce 5**	**Average**
2006	-16.3	-5.8	3.1	-17.3	-12.2	-9.7
2007	-20.5	-8.2	1.3	-20.6	-7.2	-11.1
2008	-24.9	-18.1	-14.4	-18.9	-21.4	-19.6
2009	-35.1	-21.7	-14.9	-42.4	-30.8	-28.9
2010	-48.4	-39.8	-32.9	-46.1	-35.9	-40.7

Table 2. Radial increment drop (real from predicted) in influenced coniferous stands in last year depending on tree distance from inundation edge

Year	Pine sample stands			Spruce sample stands		
	Sample tree distance from inundation edge, m					
	1 - 15	15.1 – 30	30.1 - 50	1 - 15	15.1 - 30	30.1 - 50
	Radial increment decrease from predicted, %					
2010	-45.6	-26.9	-18.6	-41.5	-20.9	-19.4

Table 3. Cumulative additional increment in influenced coniferous stands in last year depending on tree distance from inundation edge

Year	Pine sample stands			Spruce sample stands		
	Sample tree distance from inundation edge, m					
	1 - 15	15.1 - 30	30.1 - 50	1 - 15	15.1 - 30	30.1 - 50
	Cumulative additional increment, m^3ha^{-1}					
2010	-5.41	-2.36	-2.53	-12.78	-10.73	-9.55

in percentage is given.

From average increment values (Tab. 1) it is clear that pine and spruce stands show fast and similar drop in radial increments in effect of inundation. In the end of 5 year period of inundation influence the radial increment in both tree species stands has decreased by about 40%. These values are representing all sample tree average reaction in all transect area and don't show effect of tree distance from inundation edge. Tree division in distance zones 1 - 15, 16 – 30 and 31 – 50 meters from inundation edge shows clear view on response reaction of trees. These data is given in Table 2 and shows that trees in 1 – 15 m distance from inundation edge are most influenced ones' with biggest drop in radial increment. In other distance zones (16 – 30 and 31 – 50 m) this drop is smaller and mutually similar.

Calculation of cumulative additional increment in influenced stands done depending on measured tree distance from inundation edge and represents inundation influence of 5 year period. In this case cumulative additional increment indicates negative additional increment which "works" against natural increment by slowing down total volume formation on certain area. For example, data shows about 5,5 m^3ha^{-1} volume increment loss in 5 year period of pine trees growing in distance of 1 – 15 m distance from inundation (Table 3). In spruce stands this result is about 2 times bigger (about 13 m^3ha^{-1}). Cumulative additional increment changes are influenced by tree annual natural increment in the same direction (-/+) and proportion.

From last two tabeles it is clear that beaver-made inundation creates negative influence on coniferous tree (pine and spruce) increment and timber volume formation. Negative cumulative additional increment has tendency to decrease with sampling tree withdraw from inundation side but holds higher in spruce stands. Data from Table 2 shows quite similar radial increment drop of both tree species counting in percentage, but numbers of Table 3 spruce stands have much higher negative cumulative additional increment. Explanation of this situation can be average age diferences of pine and spruce stands – spruce stands (65 – 67 years old) are in period of higher annual increment than pine stands (81 – 85 years old) and spruce stands are with higher stand density.

CONCLUSION

Beaver-made inundations create nagative effect on pine and spruce annual growth, which in 5 year period can reach up to 5,5 m^3ha^{-1} in pine and 13 m^3ha^{-1} in spruce stands till 15 m distance from inundation side. After 15 m distance from inundation side the negative effect decreases and more sharply in pine than spruce stands (cumulative additional increment accordingly -2,5 and -9,5 m^3ha^{-1}).

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Received: 19.04.2011.
Accepted: 08.12.2011.