

Examination of structural constraints in relation to site condition in black spruce chronosequence

Akira OSAWA¹, Takuya KAJIMOTO², Yojiro MATSUURA³ & Nahoko KURACHI⁴

¹Faculty of Intercultural Communication, Ryukoku University, Ohtsu, Japan

²Kyushu Research Center, Forestry & Forest Products Research Institute, Kumamoto, Japan

³Forestry & Forest Products Research Institute, Tsukuba, Japan

⁴Hiraoka Forest Institute, Ohtsu, Japan

1. INTRODUCTION

Structural development of crowded plant populations has been suggested to consist of three different phases when viewed in terms of a relationship between aboveground biomass and stand density (Prentice & Leemans 1990; Fig. 1). Plants grow in size without little mortality at phase I. Subsequently (phase II), the stand follows the self-thinning line with a slope of *ca.* -0.5. Finally (phase III), stand density continues to decline without much change in biomass around its nearly constant value. There have been numerous examples confirming validity of phase I and phase II (Yoda et al. 1963, Yoda 1971, Harper 1977, Osawa & Sugita 1989, Osawa et al. 2003). Existence of phase III is more debatable. Model simulations showed its presence (Prentice & Leemans 1990), and argued it to be characteristic of ecosystem maturity. However, observation of phase III in real populations has been few. Data showing phase III were discussed for managed hardwood forests (Harper 1977, White 1980). However, they were interpreted to be results of tree harvesting (Harper 1977). One experiment showed loss of density-dependence in

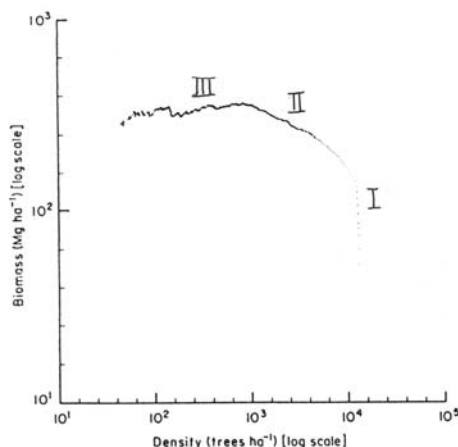


Fig. 1. Simulated biomass-density relationship for even-aged *Pinus* stand. (Modified from Prentice & Leemans 1990)

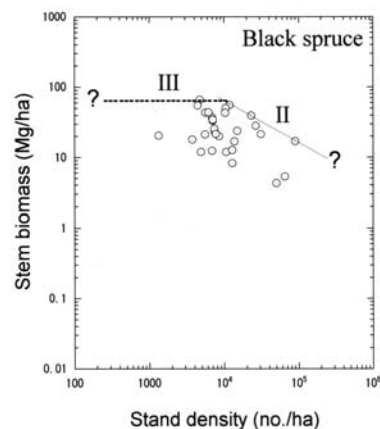


Fig. 2. Biomass (stem) vs. density relationship of black spruce in MacKenzie delta, N.W.T., Canada.

aboveground biomass for plants growing under dim light (Lonsdale & Watkinson 1982). Infertile soils may also cause plants to die with little change in total biomass (Morris 2002). We have indicated that *Larix gmelinii* forests of central Siberia show clear pattern of phase III when the trees grow over continuous permafrost (Osawa et al. 2003). We further argued that this is not only a phase of stand development, but also indicates an alternative self-thinning line for the species (Osawa et al., *in preparation*).

Objective of the present study is to examine if phase III of stand development be observed among black spruce forests of Alaska and its adjacent localities in northwestern Canada (Fig. 2). The populations growing on continuous permafrost will be examined in detail. We also plan to examine if the constant value of biomass (at phase III), if present, can vary depending on site condition. Site condition may differ depending on the depth of soil active layer and other causes. Patterns of development in aboveground biomass and its components, root biomass, plant mortality, and spatial pattern of leaf distribution will be described among stands representing chronosequence after stand-replacing forest fires.

2. METHODS

2.1 Stand selection and measurement

Pure or nearly-pure stands of black spruce of various stand ages will be located in Alaska, U.S.A., Yukon, and MacKenzie delta in Northwest Territories, Canada. The stands will be chosen so that populations of various active layer depths are included. Following variables will be measured in each stand to allow the intended comparison: stand density, stem diameter at breast height (*dbh*), stem diameter at 30 cm aboveground (D_{30}), stem diameter at lowest living branch (excluding branches of layerings) (D_B), and height of all living trees. Trees for measurement will be chosen by following the Wandering Quarter Method (Catana 1963, Osawa & Allen 1993). Trees of all sizes will be included as potential individuals for measurement. However, apparent layerings will be excluded.

2.2 Biomass equations

Trees of various sizes will be harvested in small number of selected stands. Tree dimensions will be measured as above, and biomass of each component will be measured by separating and sampling different organs. Root system will be excavated by hand, and weighed. Samples will be dried in oven for calculation of fresh/dry mass ratios. Then, regression equations will be developed to calculate individual dry mass of stem, branches, leaves, roots, etc.

2.2 Site condition

Site condition will be estimated by two means. First, mean tree height of a stand is calculated, and is used as a measure of site condition. This is a common

method of assigning site index in Russian literature (Usoltsev 2002). Second, depth of soil active layer will be measured in late summer or early fall using a soil penetrator with 5 km head mass. Mean of several measurements will be used as the depth for each stand.

2.3 Accumulation of stand data

Data of aboveground biomass and stand density will be compiled for each site condition, so that they would allow discussion of phase II and phase III in black spruce. Our experience in Siberia suggests that a few hundred stands should be measured to allow meaningful statements. We have already measured about 30 stands of black spruce in MacKenzie delta. UAF group may provide us existing data of about 90 stands. Measurement of additional 100-200 stands may be required for discussion of development of a representative site.

2.4 Description of stand development

Obtained data will be organized to describe possible development of stand structure and stand characteristics for a given site condition. Patterns of partitioning in fixed organic matter among organs, growth and death of individuals, development patterns of leaf biomass and three-dimensional leaf distribution in canopy space will be described or inferred. Then mechanisms of structural stand development in black spruce will be discussed.

3. POSSIBLE RESULTS

We have recently summarized a possible pattern of forest development after major fires for stands growing over continuous permafrost. Data for discussion came mostly from Siberia and for larch forests. However, we consider that something very similar probably applies to black spruce forests of northern North America. Suggested patterns of development include the following. First, leaf biomass of a stand may reach a maximum at relatively young stand age. It was suggested to be about 30 years for *Larix gmelinii*, after which leaf biomass declines only to about a quarter of the maximum. Second, self-thinning relationship (phase II) is observed until about age 30 years. Presence of a constant maximum aboveground biomass (phase III) becomes predominant after that (Fig. 2). Change in depth of soil active layer (its recovery) at stand age ca. 30 years is probably related to the shift in the pattern of stand development. Either (or both) lowering soil surface temperature or (and) change in patterns of nutrient dynamics may be the cause (Osawa et al. 2005). We conjectured (Osawa et al. 2005) that leaf distribution in canopy, tree size at mortality, size inequality of living trees, and light condition on forest floor may also change before and after the shift in stand development. All these parameters are planned to be examined for black spruce populations in the proposed study.

4. REFERENCES

- Catana, A.J. Jr. 1963: The wandering quarter method of estimating population density. *Ecology* **44**, 349-360.
- Harper, J.L. 1977: *Population Biology of Plants*. Academic Press, London.
- Lonsdale, W.M. & A.R. Watkinson. 1982: Light and self-thinning. *New Phytol.* **90**, 341-445.
- Morris, E.C. 2002: Self-thinning lines differ with fertility level. *Ecol Res.* **17**, 17-28.
- Osawa, A. & R.B. Allen. 1993: Allometric theory explains self-thinning relationships of mountain beech and red pine. *Ecology* **74**, 1020-1032.
- Osawa, A. & S. Sugita. 1989: The self-thinning rule: another interpretation of Weller's results. *Ecology* **70**, 279-283.
- Osawa, A. et al. 2003: Anomalous patterns of stand development in larch forests of Siberia. *Tohoku Geophys. J. (Sci. Rep. Tohoku Univ., Ser. 5)* **36**, 471-474.
- Osawa, A., T. Kajimoto, A.P. Abaimov, Y. Matsuura, N. Kurachi, O.A. Zyryanova, N. Tokuchi & K. Kondo. 2005. Forest stand development and carbon accumulation on perenniary frozen soils: Observed patterns, mechanisms, and related hypotheses for Siberia and northwestern Canada. Pages 182-185. In H. Tanaka (ed.). *Proceedings of the Sixth International Conference on Global Change: Connection to the Arctic (GCCA6)*, Tokyo, Japan.
- Prentice, I.C. & R. Leemans. 1990: Pattern and process and the dynamics of forest structure: a simulation approach. *J. Ecology* **78**, 340-355.
- Usoltsev, V.A. 2002: *Forest Biomass of Northern Eurasia: mensuration standards and geography*. Ural Branch of Russian Academy of Sciences, Yekaterinburg. (in Russian)
- White, J. 1980: Demographic factors in populations of plants. Pages 21-48 in O.T. Solbrig, editor. *Demography and evolution in plant populations*. University of California Press, Berkeley, Calif, U.S.A.
- Yoda, K., T. Kira, H. Ogawa & K. Hozumi. 1963: Self-thinning in overcrowded pure stands under cultivated and natural conditions (Intraspecific competition among higher plants. XI). *J. Inst. Polytech. Osaka City Univ., Series D* **14**, 107-129.
- Yoda, K. 1971: *Forest Ecology (Shinrin no Seitai-gaku)*. Tsukiji Shokan, Tokyo. (in Japanese)