The Role Of Bryophytes in Forest Decline and Forest Succession

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Abstract

This paper examines the bryophyte-paludification hypothesis introduced by Klinger (1990) which claims that mature upland forests develop into a stable climax bog community in the absence of large-scale disturbance. The primary mechanism of this process is dictated by the ground cover of bryophytes that kill fine feeder tree roots. This minute activity of forest decline elevates into a broader scale transition from forest to bog ecosystems. This phenomenon of forest decline is understood to be a natural process of ecosystem dynamics. Various positive and negative feedback mechanisms of bryophytes were investigated to obtain a better understanding for designing the research experiment. I describe an observational field experiment designed to test and prove the bryophyte-paludification hypothesis. Results from research indicate that due to the short sampling time frame, no initial comparisons can be drawn from the collected data. However, these results will be used as a baseline to compare subsequent samplings in the future.

Introduction

For years, researchers have tried to establish a causal relationship between acid rain or air pollution and forest decline. Studies conclude that air pollution and acid rain only contribute to a small portion of the overall patterns of forest decline (Tamm 1976; Cogbill 1977; Evans 1984; McLaughlin and Braker 1985; Klein and Perkins 1987;

Woodman 1987; Blank et 1988). By focusing more on the biological factors contributing to forest decline, a better understanding of the forest decline process can be reached.

The potential influence of biological agents in the process of forest decline has not been well investigated (Klinger, 1990). Bryophytes (mosses) have recently been shown to be abundant in areas of forest decline with no indication of unnatural tree death. Bryophytes are nonvascular plants that create unhealthy habitat for fine tree roots and mycorrhiza (fungi that are symbiotic with tree roots) by disturbing the water drainage processes and acidifying the soil. Bryophytes appear to play an important role in forest decline by altering the soil and fine tree root matrix (Klinger, 1990; Cornish, 1999).

Patterns in soil development are recognized to be closely related with successional changes in vegetation (Klinger, 1996). The characteristics of the soil profile contain evidence of the feedback process between soil structure and the development of bog communities. Initial indicators of bog formation are the abundance of moss growth and altered soil favoring further moss development. Forest decline as a process of succession involves moss invasion, soil alteration, and impeded water drainage.

The primary focus of this research project involves investigating the biological influence of bryophytes in forest decline through the transition of vegetation. By investigating the biotic factors of successional change, my research mentor and I designed this project to study the coupling relationship between bryophytes and the growth of tree roots and mycorrhiza fungi. The process of transition from forest to bog landscape is called paludification. By looking at the elements of transition in forest ecosystems. we planned to find a pathway for explaining forest decline as a natural process of succession.

Forest Succession Theory

Succession is the process of vegetation transition from one system to another compositionally different system. Succession in sequential stages refers to the colonization of a new environmental state in a series of vegetation communities until a state of equilibrium is attained. The final stage of succession is defined as the climax state. This climax state is characterized as a stable environment that would need a large perturbation to throw it out of its consistent state. The pathway of transition is often altered by disturbances that can set the succession stage back to an earlier state. These conditional changes in the landscape can be organized into two categories: allogenic and autogenic. Allogenic successional processes are composed of environmental factors such as climate change and physical disturbance. Autogenic changes are biologically controlled through community succession.

The bog climax hypothesis suggests that in the absence of perturbation, the successional transition will lead to a stable bog community as the climax stage (Klinger, 1990, 1991; Klinger et al., 1990). Under the bog climax hypothesis, the typical shift of early successional stages is due to allogenic factors and the later successional stages are due to autogenic factors (Klinger, 1996; Odium, 1992).

The two main theories of forest succession are the Climax Theory and the Individualistic Theory. The Individualistic Theory proposed by Gleason in 1926 holds that two factors, the immigration of plant seeds and the variable environment, determine the successional pathway. Therefore, the rate of succession, type of foliage that will succeed, spatial patterns, and time frames cannot be predicted, and any likeness in foliage and spatial patterns is accomplished merely by chance.

The Climax Theory (Margalef, 1963; Odum, 1969) states that succession is a predictable process of development in which one community is established and is then replaced by another community. The climax system is a structurally stable system typically symbolized as an old-growth forest that exhibits maximum biomass and contains symbiotic relationships between organisms.

This research paper derives a combination of the two main successional theories. Klinger has developed this method for explaining the successional stages he has observed and studied (Klinger, 1991). Klinger believes that the initial stages of succession are directed by allogenic (environmental, Individualistic) factors. However, the later stages of succession are determined by autogenic (biologic, Climax) factors. Klinger further believes that instead of old growth forests being the climax community, forests further decline into a peatland and eventually a bog dominated primarily by bryophytes (moss) and peat.

Forest Decline

Forest decline or "dieback" is described as the loss of tree vigor, health, or as standing dead.

There are many hypotheses about what causes forest decline. There are common mechanisms such as fire, wind, erosion (mudslide), and flooding. There are many other mechanisms such as insects, fungal pathogens, and epiphytes such as mistletoe that contribute to forest decline. There are also other causes for forest dieback that have not been explored. The focus of this research is on one main theory that covers the unexplored areas of forest decline: The Natural Decline hypothesis.

Natural Decline Hypothesis

Some studies have focused on the naturally occurring incidents of forest decline (Auclair, 1987; Hamburg and Cogbill, 1988). The Natural Decline hypothesis proposes that natural occurrences such as high temperatures (Auclair, 1987; Hamburg and Cogbill, 1988, as cited in Klinger, 1990), drought, (Hursh and Haasis, 1931, as cited in Klinger, 1990), insect infestation (Busing et al., 1998, Sherman and Warren, 1988, as cited in Klinger, 1990), are the reasons for forest dieback. These examples of natural decline cannot explain all incidents of dieback, but the symptoms and patterns of natural decline can be noticed worldwide. One of the Natural Decline hypotheses is the Bryophyte-Paludification hypothesis.

Bryophyte-Paludification Hypothesis

Klinger introduced this hypothesis which states that forest dieback relates to the coupling process involved with bryophytes that chemically alter the soil to create ideal habitat for bogs (Klinger et al., 1990). Paludification is the process of establishment and growth of peat-forming vegetation on both dry land and bodies of water (Auer, 1928). This term has also been recently expressed in succession as the passage of dry land communities to bogs in many regions around the world (Katz, 1926; Drury, 1956; Lawrence, 1958; Heinselman, 1963, 1970; Walker, 1970; Klinger, 1990; Klinger et al., 1990). Within the Bryophyte-Paludification hypothesis, Klinger developed 8 hypotheses to serve as the framework for testing these phenomena. This research project centers on utilizing the first hypothesis, which states that bryophytes influence mortality of very fine tree roots in surface soils. The role of bryophytes as the initial agent of forest decline is consistent with other research (Lawrence, 1958; Banner et al., 1983; Nobel, 1984; and Klinger, 1988). The patterns of forest decline related to bryophytes vary depending on the coupling relationship between the two.

Feedback Mechanisms in the Bryophytes – Paludification Hypothesis

Positive Feedback Mechanisms

Cooler atmosphere can create ideal habitat to sustain bryophytes. A cooler atmosphere facilitates increased bryophyte production and thus increases the potential for soils to become more acidic and reduces microbial decomposition. Reduced decomposition results in accumulation of peat, dead organic matter that hasn't fully decomposed. Increased peat can impede drainage that in turn favors the formation of peatland (paludification). The advance of peatland over large areas promotes cloud cover that has a cooling effect, sustaining the bryophyte-enriched habitat. This method of cooling also acts as a feedback loop by allowing bryophytes to sustain a cooler climate and enhance population expansion.

Another positive feedback mechanism is that bryophytes help snowdrifts accumulate around trees where bryophytes are abundant. Snowdrift cover over bryophyte populations helps sustain the moisture content necessary for their survival. The canopy helps sustain this cool microclimate by shielding the snow and bryophytes beneath from direct sunlight.

Images taken from the digital camcorder were analyzed and imported to a computer (via Photo DV) for improvement. Only images containing roots were imported into the RooTracker program for analysis. The primary focus of using the RooTracker program was to obtain the mass, length, width, and level of branching of tree roots and mycorrhizae.

Results

Results from the minirhizotron analysis at Niwot Ridge show that root volume under mossmats was equalivant to root volume at moss-free sites. The Niwot Ridge data represented had very little root growth due to limited recovery time. The results from the Lefthand Creek site are still being analyzed and have been excluded from the analysis in this paper. By comparing root volume and root abundance in the moss and non-moss tubes, an overall even distribution is expressed (Table 1). These results represent a baseline standard that will be used for comparisons in subsequent years of resampling. These results show that the tree roots have not been given enough time to recover from the disturbance of installing the minirizotron tubes. My work will be used as a standard to compare against future research of root development.

Discussion And Conclusions

Discussion

It is apparent that the minirhizotron tubes at Niwot will be a baseline map for sampling later on. The problems that we ran into deal with the limited time that the roots were allowed to grow back around the tubes. Two tubes had to be replaced because they couldn't be sampled due to bends in the tubes caused from rocks in the installation process. They were removed and new tubes were reinstalled giving only one week's worth of root development before the video sampling had to be taken.

Field sampling techniques have improved by initializing better, more technically realistic results from using the minirhizotron camera. Establishing the Niwot research site has highlighted the importance of creating a systematic way of sampling with more precision. This precision will hopefully be further developed to allow individual roots to be monitored for health yearly.

Another indication of initial growth is that many minirhizotron tubes contained very few roots, whereas others contained a large mass of segmented roots. Initial installment of the minirhizotron tubes may have invigorated root growth in specific areas. Hopefully, allowing the sample sites to recover before sampling can solve this problem.

Conclusions

My results have established a baseline standard of the root structure and soil horizon at the Niwot Ridge research site. This initial data can be used to track root development in subsequent years of sampling. Further sampling will be needed to gain knowledge about the role bryophytes play in root mortality at the Niwot Ridge sample site. Increasing the sample size and extending the distance of each sampling group could potentially stratify and improve on the root profile at Niwot Ridge. Although the initial implications of my research have not been revealed through this year's investigation, the evidence of bryophyte influence on forest decline can now be studied at length in the future.

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