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Windthrow and forest regeneration, structure, and composition in boreal forests

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WINDTHROW AND FOREST REGENERATION, STRUCTURE, AND COMPOSITION IN BOREAL FORESTS

by

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ABSTRACT

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Key Words: boreal forests, forest restoration, structure, composition, uprooting, forest ecosystems, windthrow, vegetation dynamics

Windthrow is a self-identified disturbance factor in forests, which has a huge ecological and economic impact.

This paper discusses the influence of windthrow on boreal forests and analyzes the changes of tree ecosystems from three aspects of forest restoration, structure, and composition. This article combines two different experiments to study boreal forests in different regions including Europe and Canada. Through systematic quantitative review and data analysis, the main factors of forest restoration and the influence of pothole topography formed during windthrow inversion on forest structure and composition were obtained.

Through the quantitative analysis of 13 boreal forest cases, the regeneration and survival of seedlings in the forests suffering from wind disasters are studied, and whether it promotes the regeneration of forests. This indicates that the soil microorganisms in the forest are the main factor that promotes forest restoration, which is also a point worthy of attention in forest management in the study of wind disturbance, the potholes in the forest experienced by the wind increased by about 10%. After the roots are uprooted, the soil becomes loose, giving the trees and seedlings good growth conditions. The terrain of each pothole is a micro-environment, which contains many microorganisms and nutrients, which provides a good growth environment for the germination of seeds and the growth of seedlings. When the growth conditions change, the structure and composition of the forest will also change accordingly. Therefore, windthrow affects the regeneration, structure and composition of forests.

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ACKNOWLEDGEMENTS

I would like to thank my thesis advisor, Dr. Han Chen, for his professional knowledge that enabled me to complete this thesis successfully. Thanks to Teacher Huang Xingzhao for answering my doubts about the impact of windthrow on the forest, and thanks to my friends who have provided me with a lot of ideas so that I can have a deeper understanding of the benefits of forest restoration to nature. Finally, I would like to thank my parents for their financial help so that I can focus on my study at Lakehead University.

INTRODUCTION

There are many natural disturbance factors in the ecosystem, such as windthrow, fire and human disturbance. These factors can alter resources and the physical environment, and thus affect ecosystems, communities, or populations. In the boreal forest, windthrow is a common disturbance, which can cause substantial economic loss and ecological damage under hurricane damage. Windthrow can change ecosystems. For example, windthrow can spread pathogens and pests, and destroy parts of vegetation. The loss of vegetation changes the habitats and food sources of animals and other living things. The organic materials and minerals in the haystack can be used as fertilizers to improve site productivity. The windthrow can spread seeds over long distances, so when the seeds of different types of trees spread into the forest, and these seeds take root and sprout, the forest composition can be changed. Windthrow will destroy forest structure to a certain extent and affect forest restoration. Therefore, the structure and composition of forest restoration caused by windthrow have become the top priority of forest management.

Windthrow affects forests spatially, so the hierarchical nature of forest structure must be considered in the research. The forest after littering mainly depends on the regeneration mechanism. Trees with strong roots may survive the wind and form canopy gaps. The development of these gaps is conducive to the survival and development of forests. This article focuses on the impact of northern forests. Most of those that could not stand the windthrow were uprooted or broken. The uprooted trees form a cave-like terrain, which provides good growth conditions for seed implantation. Therefore, the virgin forest in the north is rich in trees and vegetation species of different ages, thereby increasing the stability of the ecosystem. Therefore, it can be judged that the adaptability of the trees to the environment gradually increases after experiencing a strong windthrow.

1.1 Objective:

The purpose of this paper is to analyze the data of 13 different boreal forest cases. Due to the small amount of research data, a systematic quantitative review and data analysis were carried out to improve the credibility of the data, and to analyze the credibility of the renewal, structure and composition of aeolian forest. This article will provide information on the significance and impact of each set of data, as well as discuss quantitative and qualitative assessments of post-storm regeneration, surviving trees, and nutrient regeneration in the forest restoration process. This paper focuses on the effects of windthrows on relevant forest management, and understanding natural restoration mechanisms that help forest recovery, structure, and composition.

1.2 Hypothesis:

Windthrow resistance hinders forest restoration and will have a negative impact on forest. Windthrow resistance changes the structure and composition of the forest, increases the diversity of forest species, and promotes the stability of the ecosystem.

2.0 LITERATURE REVIEW

2.1 WINDTHROW

Disastrous windthrows can be classified as storms, gales, cyclones, hurricanes, and tornadoes. Windthrow damage can be measured by structural loss (stem damage) and component loss (stem mortality). The destruction involves both biological and abiotic factors (Bouchard et al. 2009).

The wind speed determines the extent of the destruction of the forest（Bouchard et al., 2009). Analyzed the probability of windthrow disturbance in stands at different locations and obtained the possibility of windthrow disaster in the future. The results show that the probability of windthrow disaster in the south is greater than that in the north, and the probability of southwest windthrow to southeast windthrow is greater (Everham and Brokaw. 1996)

windthrow plays an important role in forest dynamics in eastern Canada (Saal et al. 2017), and it generates si gnificant e conomic losses. Studies have s hown that hurricanes are more li kely to o ccur in temperate re gions than in c older regions, and tend to generate extreme wind speeds. The frequency of gusts is increasing in Canada due to global warming(Saal et al. 2017). In addition to windthrow speed, changes in soil freezing mechanics also affect the risk of windthrow damage(Saad et al. 2017). As permafrost increases the fixed point of trees, trees are more likely to be uprooted and cause more damage when the windthrow becomes stronger and stronger in the case of global warming. By analyzing the history of wind speed changes in Newfoundland, Ontario, in eastern Canada, predicting future wind speed greenhouse gas emissions based on permafrost and permafrost research within a year, and assessing wind speed risks (Saad et al. 2017). Determine the final wind speed according to seasonal changes. In the boreal forest, balsam fir is most easily blown down by the wind. When other climate changes are not taken into account, wind speed and permafrost can predict the future wind direction of eastern Canada's forests.

2.2 FOREST REGENERATION

Windthrow is an important factor affecting forest dynamics. Windthrow intensity affects many aspects of stand structure, such as age, height, density, and species composition.The same strength of the windthrow in different locations will produce different effects. For example, certain geographic locations may affect the direction and strength of the wind. Therefore, when analyzing the forest renewal, the direction of the wind can be analyzed first. Composition and composition requires multi-angle analysis. Forest regeneration is achieved through the dynamics of forest restoration. There are four ways for stands to regenerate after a storm: regeneration, recruitment, release and inhibition. (Everham and Brokaw. 1996)

Through the analysis of two areas with different proportions of coniferous forests in northern Japan, the restoration capacity of Japanese coniferous forests is analyzed from the aspects of coniferous forest reserve, coniferous forest species advantage and future coniferous forest reserve(Junko et al. 2019). The disturbance is divided into three types: windthrow (WT), windthrow + SL, Old Growth (OG) Breast Height (DBH) >=5cm, and the tree species name is recorded. Through 50 years of research, this experiment has concluded that under the influence of WT+SL, the influence of conifers in the northern mixed forest is more abundant than that of WT and OG. In the mixed forest, the number of conifers affected by WT+SL is much lower than that of WT and OG (Junko et al. 2019). Therefore, it can be inferred that the migration and felling of trees will affect the survival of coniferous trees in the storm, which also leads to fewer coniferous trees in the northern mixed forest disturbed by WT+SL. In the coniferous forest, the same WT+SL did not significantly reduce the impact on the coniferous forest.

2.3 FOREST COMPOSITION

Taylor, A. R., E. Dracup et al., using augmented regression analysis, explored the effects of climate, topography, soil and forest structure variables on windthrow direction. Among them, stand height and species composition had the greatest influence on windthrow direction(Taylor et al. 2019). For A single-rooted stand with tall trees, the effect of windthrow may be greatest. Of these influences, terrain has the least effect on windthrow. Four variables of windthrow damage threat: 1. The meteorological variable of the windthrow itself. 2. Topographic variables can affect the growth of trees. 3. Soil fixed to tree roots. 4. Windthrow resistance of trees(Taylor et al. 2019). When the windthrow moves across A valley or A mountain, there is A great possibility of changing the direction of the windthrow. Trees with strong drainage capacity and deep roots have strong soil anchorage. They were divided into small units using aerial photographs. 5, 000 intact forest units and 5, 000 stand replacement units were selected from the area experiencing the hurricane. The analysis showed that continuous windthrow was positively correlated with height distribution, and canopy could reduce windthrow interference. Coarse soil is less susceptible to hurricanes, while windthrow-exposed locations are more susceptible to hurricanes.

2.4 FOREST STRUCTURE

Windthrow-induced forest disturbances include trees, stands, landscapes, and soil. Through the study of the adaptability of trees, the limitation of economic growth in the competition between trees, the influence of repetitive bad weather, terrain and soil conditions on the station and the influence of windthrow disturbance on the station dynamics, the role and influence of windthrow in the forest is deeply understood and the prediction of windthrow direction(Mitchell et al. 2013). Trees are structured to withstand certain windthrows and compete for resources for their own growth and development. If the windthrow is strong enough, trees may be broken off or uprooted. This affects the survival of the tree, but as long as there is room, new trees will sprout and take root. Windthrow swept forests can turn living trees into fallen wood chips or dead trees. Therefore, the windthrow can destroy the forest structure to some extent.

There are many reasons for the difference in forest landscape caused by windthrow disturbance, and its influence depends on the spatial layout of the forest ecosystem. A multiple regression model was used to predict the density index, tree species and stand age. The results showed that, with the increase of diameter, the mortality rate of the species increased gradually when the intensity index remained unchanged. (Rich et al. 2007) When the diameter was constant, the mortality of species was proportional to the intensity index. The sensitivity of mature stand to canopy mortality was higher than that of the old stand and very old stand(Rich et al. 2007).

2.5 BIODIVERSITY

Climate is an important factor in determining species diversity. The effects of growth days (GDD), climate humidity index (CMI), soil drainage grade (SDC) and stand age (SA) in Canada on plant diversity were studied (Yi et al. 2014). The model was established when the canopy tree species richness was 47%, the Simpson dominance index was 30%, and the total plant species richness was 49%. The study found that canopy richness is proportional to GDD and CMI, while SDC and SA are the highest. The Simpson Advantage Index is inversely proportional to GDD and CMI, while SDC and SA are the lowest. The total species richness is closely related to SDC (Yi et al., 2014).

The diversity, abundance, and environmental conditions of the restored and unrestored wind forest micro-habitats in western Tennessee, USA will be regenerated. The results showed that there were more species of microdots in the remediation area, the richness of microdots increased, the soil temperature was higher, and the canopy openness was higher (Peterson and Leach. 2008). However, after two years of storms, there was no difference in species richness between felled and unfelled areas, and soil moisture was affected. The environmental conditions and vegetation characteristics of microstations are different. The pit formed by uprooted trees is a microenvironment. These individual microenvironments can support the growth of precious trees in damaged forests to increase or maintain tree diversity, and may be important in determining future species composition(Peterson and Leach. 2008).

As an important part of the forest ecosystem, wood becomes a habitat for microbial, insect, plant and animal communities through natural decomposition. This is done by degrading fuels produced that are highly susceptible to forest fires. Those uprooted trees will bring a lot of mineral soil to the ground. The formation of pits leads to microscopic topography, promotes the diversity of plant root area under the forest, and affects the succession path (Mitchell S.J. 2013).

Loss and fragmentation of habitat quantity and quality has become the biggest threat to biodiversity today (Hekkala et al. 2016). The number, diversity and continuity of dead wood are important factors affecting the diversity of dead wood dependent species. Using experimental forest and control group, how to improve the utilization rate of dead wood was evaluated. In the short term, the amount of dead wood can be increased by cutting down. The final results showed that future shoot continuity was not affected within a moderate cut range (20% of initial volume). If logging is not controlled, the continuity of dead shoots at the stand level will be affected. A large number of dead branches does not mean diversity of dead branches(Hekkala et al. 2016).

2 MATERIALS AND METHODS

2.1 LOCATION OF CASE STUDY

In this paper, boreal forests are selected for study, which are located in Canada and European countries, among which 13 cases are from Europe and Canada. (Boreal Sites in Figure 1)

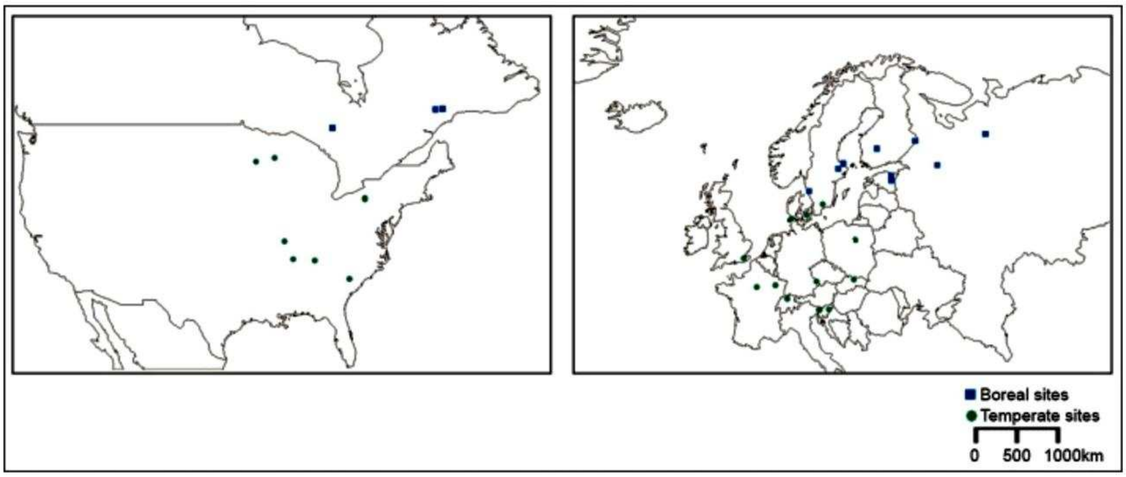

Figure 1. Study locations in the analysis.

In Russia, after consulting the literature and reviewing the literature of others, we selected the well-preserved northern coniferous forest as the research object, and mainly investigated the Eastern European coniferous forests in the Central Forest Reserve, including the fir (L.) birch forest (Betula Pendula Roth) and the forest law Cloth (Fabus Sylvatica L.). It is located in the center of the Russian plain southwest of the Vardi Highlands in the watershed between the Volga and Sidvina rivers. This area is located west of Rzhev, between latitude 56°26' and 39' n, between longitude 32 m 39' and 31°01', with an altitude of 300 m. The surface geology is dominated by a 10 m thick ice ora deposit. (Taeroe et al. 2019) Ten sample plots were selected in this area and four different forest types were studied. These forests were unevenly stood and had not been felled or burned in the past 100-200 years.

3.2 RESEARCH METHODS:

In the analysis of 13 cases from Europe and Canada (Table 1), we first performed a statistical analysis of their data, but since the number of cases was not large enough to provide sufficient evidence, we resorted to a quantitative review. The results come from a "quantitative assessment" and a "qualitative assessment" used to discuss the positive and negative effects of windthrow on forest regeneration and composition. (Ulanova 2000)

Table 1. Case studies included in the analyses. (Ulanova 2000)

Site	Biome	Main species	Year of assessment	Year of assessment	Forest type	Investigated
Siggaboda, Sweden	Boreal	P. abies, F. sylvatica	2005	2004-2011	Forest reserve	Free succession
Labra Park, Sweden	Boreal	P. abies, Q. robur	1969	1974-1984	Forest reserve	Salvage logging
Fiby, Sweden	Boreal	P.abies	1796	1984-1988	Forest reserve	Free succession
Nuijakorpi, Finland	Boreal	P.abies	1950	2001	Forest reserve	Free succession
Petkeljarvi, Finland	Boreal	P. sylvestris	1982	1994	Forest reserve	Free succession
Tudu, Estonia	Boreal	P.abies	2001+2002	2005	Forest reserve	Free succession Salvage logging
Halliku, Estonia	Boreal	P.abies	2001+2002	2004-2007	Forest reserve	Free succession
Tudu, Estonia	Boreal	P.abies	2001+2002	2004+2010	Forest reserve	Free succession
Arkhangelsk, Russia	Boreal	P.abies	1990-2006	2009	Forest reserve	Free succession
Vepssky, Russia	Boreal	P.abies	1983+1985	1971-2006	Forest reserve	Free succession
North Shore Quebec, Canada	Boreal	P. Mariana, A. Saccharum	1977	2004	Managed forest	Free succession Salvage

						logging
North Shore Quebec Canada	Boreal	A. Balsamea , P. mariana	2011	2011	Managed forest	Free succession

We have divided the results of the eight key points affecting forest restoration and forest structure into three categories, the first being quantitative assessment, the second qualitative assessment and the third unassessed. Eight points refer to Post storm regeneration, surviving trees, plant growth, soil disturbance, Coarse woody debris, Seed source proximity, Competing ground vegetation, and Pests and diseases. Among them, surviving trees, advanced regeneration and plant growth are the possible factors affecting forest restoration; soil disturbance, Coarse woody debris, seed source proximity, competing ground vegetation, pests and diseases are the possible factors affecting forest structure.

After the results are obtained, the quantitative evaluation can establish a mathematical model to evaluate each indicator according to the statistical data. Qualitative assessment can be based on a specific description and material analysis to give the corresponding results.

The three elements related to forest restoration are classified into three different levels, of which the first level is dominant, the second level is co-dominant, and the third level is secondary or non-existent. The five elements of forest structure are also classified into three levels, of which the first level is important, the second level is secondary and the third level is insignificant. According to the hierarchical and quantitative classification of different factors, which factors are important factors leading to forest restoration and forest structure change can be determined.

A map of all trees and shrubs, including tree species, trunk height (DBH) and age, in a ratio of 1:100, was made for the sample site in the Russian region. List the locations to be pulled out on a map and draw the corresponding pits. At each sample site, the distribution of pits is determined. We can estimate the coverage of individual trees, shrubs, herbs and bryophytes. Changes in forest composition were confirmed by measuring changes in the number of field species in four different spruce forests.

4.0 RESULTS AND ANALYSIS

The study looked at boreal forests in 13 different areas, including three in eastern Canada and 10 in northern Europe. As the number of studies has decreased, we need to combine quantitative analysis with qualitative analysis. Finally, the impact of windthrow on forest restoration is based on the impact of these eight factors to judge the forest structure.

4.1 QUALITATIVE AND QUANTITATIVE ASSESSMENT OF EIGHT FACTORS

Table 2. Research efforts (number of investigations) on recovery processes and influencing structures and processes. Te is temperate, Bo is boreal(Ulanova 2000).

	Assessed quantitatively	Assessed qualitatively	Not assessed
Post storm regeneration	10	3	0
Surviving trees	7	3	3
Vegetation regrowth	1	3	9
Soil disturbance	6	3	4
Coarse woody debris	5	3	5
Seed source proximity	1	4	8
Competing ground vegetation	2	5	6
Pests and diseases	1	3	9

In the analysis of factors affecting forest restoration, quantitative assessment of the boreal forest in 10 places and qualitative assessment of the boreal forest in 3 places were carried out in the Post Storm regeneration analysis, among which 0 places were not evaluated. In the analysis of surviving trees, boreal forests were quantitatively assessed in 7 sites and qualitatively assessed in 4 sites, two of which were not assessed. For the vegetation regrowth analysis, the boreal forest in one location was quantitatively assessed, the boreal forest in three locations was qualitatively assessed, and the boreal forest in the other nine locations was not evaluated. (table 2).

In the analysis of factors affecting forest results, soil disturbance and coarse woody debris were the most commonly used sites for quantitative and qualitative assessment, 9 and 8 respectively. There is only one place where there is a quantitative assessment, and there are nine places where there is no assessment of Seed source proximity and tobacco and diseases, eight places where there is no assessment of Seed source proximity.

4.2 INFLUENCE DEGREE OF EIGHT MAJOR FACTORS

Table 3. Importance of recovery processes and influencing structures and processes . Bo is boreal. (Ulanova 2000)

	Dominant	Co-dominant	Minor
Post storm regeneration	3	9	1
Surviving trees	0	9	1
Vegetation regrowth	1	1	4
	Important	Less-important	Not-important
Soil disturbance	7	2	0
Coarse woody debris	5	4	0
Seed source proximity	3	2	0
Competing ground vegetation	3	4	0
Pests and diseases	3	1	0

4.2.1 FOREST RESTORATION

When discussing the factors of Post Storm regeneration, 12 boreal forests showed that Post Storm regeneration played a dominant role in the process of forest restoration, while only one boreal forest showed that Post Storm regeneration was a secondary factor in the process of forest restoration. In terms of factors related to Surviving trees, Surviving trees played a dominant role in the process of forest recovery in 9 boreal forests, while Surviving trees were a secondary factor in only one boreal forest. When discussing the factors of Vegetation regrowth, only two boreal forests showed that Vegetation regrowth was dominant in the process of affecting forest restoration, while four boreal forests showed that Vegetation regrowth was a secondary factor in the process of affecting forest restoration. (table 3).

4.2.2 FOREST STRUCTURE

In the study of factors affecting the forest structure, we found that soil disturbance, Coarse woody debris, Seed source proximity, ground vegetation, Pests and diseases all have important or secondary influences on the forest structure. In the analysis of soil disturbance, boreal forest in 7 regions showed that it was an important factor, and boreal forest in 2 regions showed that it was a minor factor. In the analysis of Coarse woody debris, boreal forests in 5 regions showed that it was an important factor, while boreal forests in 4 regions showed that it was a secondary factor. In the analysis of Seed source proximity, boreal forests in three areas showed that it was an important factor, while boreal forests in two areas showed that it was a secondary factor. In the analysis of Competing ground vegetation, boreal forest in 3 areas showed that it was an important factor, while boreal forest in 4 areas showed that it was a secondary factor. In the analysis of Cures and Diseases, there are 3 boreal forests that show this to be an important factor and only 1 boreal forests that show it to be a secondary factor (table 3).

4.3 FOREST COMPOSITION

4.3.1 PIT TOPOGRAPHY DRAWING

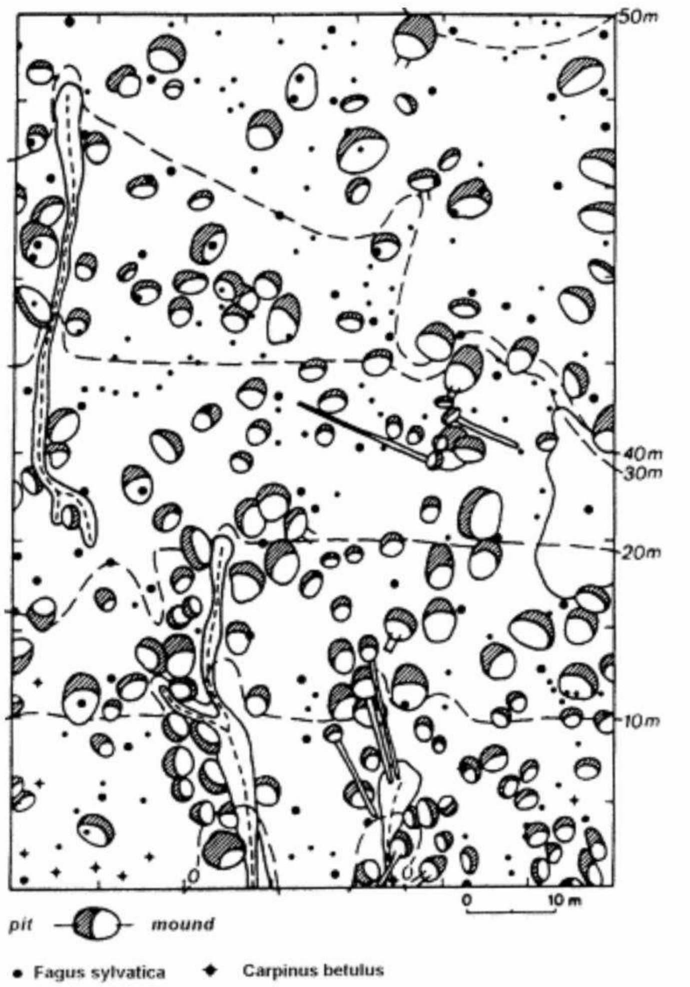

Figure 2. Patterns of windthrow in beech forest. (Nina 2000)

From the picture, we can easily find that the wind-blown forest will form many uneven terrains, accounting for about 20% of the total forest area according to the estimation of area ratio.

4.3.2 MEASUREMENT OF SPECIES NUMBER IN THE FIELD

According to the results in Figure 3, the boreal forest affected by windthrow increased the total field species richness of the four spruce forests. windthrow increases forest species richness, not just for tree species and ferns, but also for animal species in the soil.

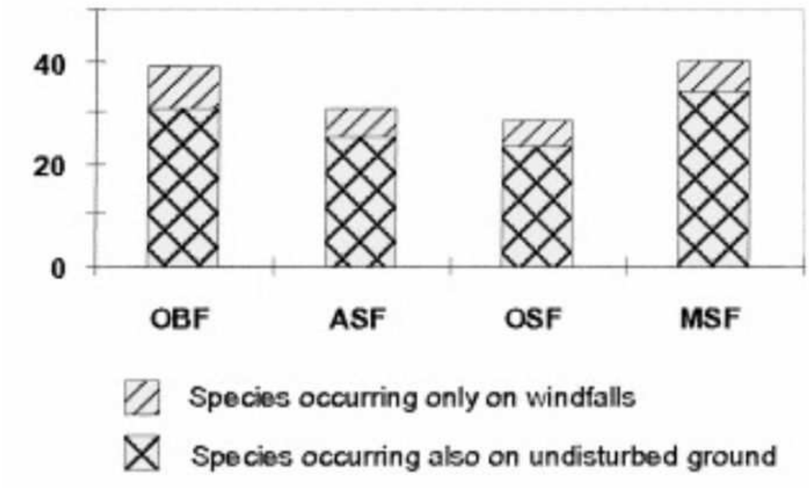

Figure. 3. Number of field-layer species in four different spruce forest types (Central Forest Reserve)(Nina 2000). The X-axis shows four different forest types: OBF, ASF, OSF, and MSF. Explanations: OBF, Oxalis type secondary spruce-birch forest, ASF, Asperula type, OSF, Oxalis type, MSF, Myrtillus type (Nina 2000).

In Figure 4, only one forest type was analyzed, and the changes of species richness after windthrow-blown tree age at 5, 40, 80, and 200 years were analyzed. Species richness in the field was highest when the tree was 80 years old. Species richness in the field was the lowest with the tree age of 200 years. So we can infer that forests of different ages have different abilities to promote species richness when the windthrow blows to the right and the left. But whenever a forest is exposed to windthrow, it increases the richness of species in the field.

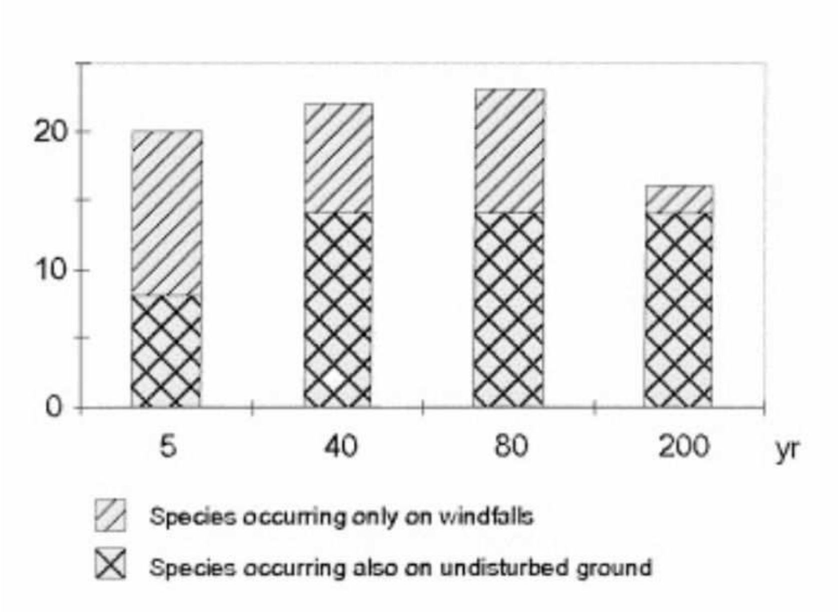

Figure. 4. Number of field-layer species in Myrtillus type spruce forest on windthrow of different ages (Central Forest Reserve) (Nina 2000).

5.0 DISCUSSION

Through the analysis of northern forests in 13 different regions, it was found that soil disturbance, rough wood chips, proximity to seed sources, ground transmission, pests and diseases, etc., all affect the forest structure, but when divided from other factors, pests and diseases are not so important. The possible reason for this situation is that the spread of pests and diseases is relatively wide, and the probability of occurrence of more serious situations is relatively low. The reason for this may be that there are many uncontrollable factors in different areas. Some of these disturbance factors change the forest structure after experiencing a storm, but it will hinder the forest recovery.

5.1 The process of forest restoration

After the forest was blown by the storm, we found that post storm regeneration and surviving trees were the two factors that mainly affected the forest recovery. The windthrow boreal forest needs to restore ecosystem stability in time, so it makes sense to germinate seeds, regenerate seedlings, and restore surviving trees. Although Vegetation regrowth is a minor factor in forest restoration, it also plays a huge role. The regeneration of vegetation can provide a good ecological environment for the habitats of animals and plants. When the ecosystem tends to be stable, species richness will be affected to some extent. As species richness increases, the ecosystem becomes more and more stable, forming a good ecosystem. However, forest recovery is a very slow process. When the windthrow has a serious impact on the forest, the number of surviving trees will decrease, and the number of trees blown down by the windthrow will increase. Although it can be restored to its pre-blown state for long enough, when the windthrow is strong enough and frequent enough, it prevents the forest from recovering.

5.2 CHANGES IN FOREST STRUCTURE

When a forest is blown away by a storm, it has an effect on the structure of the forest. Soil disturbance and Coarse woody debris play an important role, and qualitative and quantitative evaluations are carried out for several boreal forests. The potholes of uprooted trees form microbial communities that are ideal for seed development and seedling growth. A tree or branch that has been blown to the ground and turned into coarse sawdust that is broken down by microorganisms to form micro-sites suitable for the growth of young plants. There are many kinds of microorganisms that can degrade lignin, among which fungi are the main ones. Besides fungi, some prokaryotes such as bacteria and actinomycetes also play an important role in the transformation and degradation of lignin in soil. The degradation of lignin in soil is the result of the interaction of various microorganisms in soil microflora. As a result, when some trees fall, the formation of soil encourages the growth and development of seeds and seedlings, and the structure of the forest changes.

5.3 CHANGES IN FOREST COMPOSITION

The main factor affecting changes in forest composition is the bumpy landform of uprooted trees after toppling. These landforms help to form microbial communities that allow windthrow seeds to take root and germinate, changing the number of species in the field. Species diversity is the richness of the kinds of animals, plants and microorganisms. Species diversity affects ecosystem diversity to some extent, and ecosystem diversity plays an important role in maintaining soil fertility, ensuring water quality and regulating climate. Therefore, the windthrow will increase the forest species diversity, which will contribute to the ecosystem diversity to some extent.

6.0 CONCLUSION

In addition to harming the forest, wind also has an impact on the growth, morphology and forest restoration of trees. With the development of global climate change, the danger of more and stronger storms is increasing. Wind not only greatly affects the production of forest wood, but also has a great impact on the stability of the forest ecosystem. Forest wind can cause tree trunks to bend, stem (canopy) breaks, roots uprooted, and sustained damage; its occurrence is mainly dependent on meteorological conditions, geographic location, characteristics of trees and stands, and their interactions. Among them, the diameter at breast height and height of the forest, and the structural characteristics of the forest stand (tree species, composition, density, etc.) are the main characteristics that control the resistance of trees and stands to wind. Therefore, it is necessary to strengthen forest management and flexibly use different afforestation measures to reduce the impact of wind on forest restoration, structure and composition. At the same time, it is necessary to strengthen the wind risk assessment and research, and then to manage the forest; and pay attention to the changes in the structure and composition of the forest before and after the disaster, so as to provide sufficient information for the forest management and regulation after the disaster.

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