THE SIBERIAN STONE PINE FORESTS OF ALTAI MOUNTAINS: UNDISTURBED AND STABLE

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ABSTRACT

The Altai Siberian stone pine forests: undisturbed and stable.

The Siberian stone pine (*Pinus sibirica*) old-age forests of the Central Altai is an almost unique example of a natural ecosystem with a minimal direct impact of human activities All known forests of this type are isolated in the relatively undisturbed valley of the Aktru river. The forests successfully survived the Little Ice Age and demonstrate significant stability under modern climate change. The dendrochronological studies suggest these forests existed and much probably remained virtually unchanged for 650+ years in the past.

Despite the similar age and resilience these old forests exist in 4 sustainable variations; each one is the forest adaptation to the peculiarities of their respective ecotopes (degree of slope, peculiarities of the ground and soil). Full α-biodiversity of these forests includes 112 vascular plant species and 46 mosses and lichens. We believe the most important aspects of these forest stability are the exceptional ecological amplitude of adult Pinus sibirica and the powerful environment-changing abilities of this species. The significant peculiarity of these forests is the presence of cyclic succession necessary for the regeneration of the forest. The age structure of the forests suggests it can be disrupted or even stopped because of the vulnerability of Pinus seedlings and young trees to climate changes: the dendroclinatic studies indicate the forest include 2 large regeneration gaps related to significant coolings. The important element of stability which compensates the vulnerability is longevity of Siberian stone pine (average tree life span is about 550-600 years) and ability to produce seeds to the death of the tree. The current level of climate change is not strong enough to disrupt the cycle; it is more likely it is favorable for modern Stone pine forests regeneration and slow expansion of the species up by the valley slopes.

The monitoring of regeneration suggests these forests are at least stable under modern climate changes.

Keywords: *Mountain forests; Altai mountains; Siberian stone pine; Ecosystem stability;*

INTRODUCTION

The old-age forests formed by the Siberian stone pine (*Pinus sibirica* du Tour) of the Central Altai are an almost unique examples of a natural ecosystem with minimal direct imparct of human activities. All known forest of the type are isolated

in the relatively undisturbed valley of the Aktru river, but since the remote valleys was never studied by anyone we may assume the forest may exist in some other parts of the Central Altai. These forests are rara example of the stable ecosystem which outlived the climate change of the past without significant changes and successfully endure modern climate change.

STUDY AREA

Geographical location

The valley of the Aktru river (50°05' N, 87°45' E) is located in the northern slope of Severo-Chuiskiy range (Central Altai) at the altitudes 2150–2200 m a.s.l. and include the upper courses of the river and its glacier sources: The Maliy Aktru, Leviy Aktru and Praviy Aktru glaciers. The climate of the valley is generally harsh: it is relatively cold and dry. The climate data of long-term climate monitoring [1] indicate that the mean annual temperature in the valley is -5.2°C; mean summer temperatures is only +8,7°C; mean annual precipitation is about 560 mm and only about 25% of precipitation occurs in the 6 month long (November to April) winter. The modern regional level climate change studies [2] indicate the average increase of the mean annual temperature since 1980s was 3,8°C and precipitation decreased by about 10%, but exact changes for the Aktru valley is unknown.

Old-age forests

All modern Siberian stone pine forests are largely isolated massifs (massif area are from hundreds to tens hundreds sq. m.) that survived major forest fires of the late XIX century which affected larger part of the Central Altai. The burned forests were replaced by Siberian larch (*Larix sibirica*) ones which are currently typical for the Central Altai. The Aktru valley contain 5 such massifs – one on the North of the valley between the terminal rims left by receding glaciers, 2 on the North-West slope of the valley and 2 on the South-East slope of the valley.

Disturbance level

The Aktru valley is a remote area - the distance to the closest town is more than 200 km; the distance to the closest industrial center is about 350 km; the local population density is very low (2,2 men/km^2). The sole source of human impact on these forests is tourism and mountaineering, but only 2 of the forest massifs (one on the NW slope and one on the SE slope) are affected by mountaineers who often pass through the forests to reach the areas of interest. Thus the human impact on these forests is minimal and generally limited by the vicinities of the pair of trailed tracks across the se massifs. The main disturbance sources affecting these forests are strictly natural (mostly rockfalls and avalanches). The 2 remaining massifs are isolated from tourist tracks and camping areas by wide screes and one by the fast and cold glacial stream which have no other way of crossing but waist-deep ford which generally stop any tourists. Thus larger part of the Siberian stone pine forest of the Aktru valley are affected only by occasinonal natural disturbances and the forests may be considered as an almost unique for the Altai piece of wild nature virtually not affected by human activities in any form and provide rare opportunity to study the forest unaffected by any human activities for the hundreds of years.

RESULTS AND DISCUSSION

The key to the stability of the old-age forests is the ecology of the Siberian stone pine. It has a wide range: it occurs from low courses of the Vychegda river on the West to the Aldan highlands to the East (about 4500 km) and from Igarka town on the North to the upper courses of the Orchon river (Mongolia) in the South (about 2700 km) [3]. It clearly indicates the *Pinus sibirica* can survive and reproduce itself in various climates. Our previous studies allowed us to fetch out it can survive in a wide range of conditions from dry forests to swampy forests and on different soils from poor to fairly reach [4]. The wide ecological amplitude of the Siberian stone pine allowed the old-age forests of Altai to survive a number of climate changes of the past: the 500-600 years old trees outlived both LIA (Little Ice Age) and medieval warming [5]. The northern massif of Siberian stone pine provides us with an excellent example of the great stress tolerance of the species. It is located between terminal rims and survived during LIA being literally clenched between glaciers. Thus, the high resilience and amplitude of the *Pinus sibirica* is the first key moment of the forest stability.

The studies of the age structure of the Siberian stone pine forests of the Aktru river valley indicated the 3 major generations of the *Pinus sibirica* trees are present in all massifs [5]. The oldest one does not include singular oldest trees of 650-500 years which are remained from the previous generation. The first generation was formed between 1490 and 1630; the second one between 1660 and 1790 and the third one between 1840 and 1960; The the fourth generation is still forming and represented by modern young individuals of the species. The regeneration of the Siberian stone pine was not continous: during the LIA numerous gaps had occurred. The new trees settled only when several warmer years follow each other. The dendroclimatic reconstructions suggest at least 4 such periods of various duration has occurred [5]. The longevity of the *Pinus sibirica* and the fact it can produce seeds to the physical death of the tree without any senile stage of the life cycle is the second key of this forests stability. Even prolonged climate changes with duration of hundred years is not a great threat to the Siberian stone pine populations: even if the climate change impede reproduction and forest regeneration the forest will regenerate itself during fluctuations or simply outlive the changes and reproduce itself when the climate will become more suitable for the reproduction. It is necessary to mention the current climate changes is auspicious for the Siberian stone pine mountain populations which indicate stable regeneration and increase of their size because of colonization of forest-tundra ecotone.

One of the most important peculiarities of the Siberian stone pine is its powerful environment-changing influence. The Pinus sibirica is the typical forest aedificatior species: it has a competitor life strategy but unlike most common competitors have wide ecological amplitude allowing it to survive in high-stress areas and it can greatly affect the envirommentlike any other aedificator [6], [7]. The tree storey formed by the Siberian stone pine change illumination of the lower storeys (especially in the areas where stands is dense), allowing colonization of shade-requiring plant species, change wind, temperature, air humidity and snow regimes, soil composition and stabilize them making the microclimate of the forest more stable than the valley climate. The presence of strong aedificator with wide

ecological amplitude makes the ecosystem more stable, because while it is present it may support a typical microclimate and protect other species from stress.

The ecosystems of the Siberian stone pine forests have complex structure. Several spatially limited variations are exist inside the forests. Their types and species composition are determined by the peculiarities of habitat, density of the Siberian stone pine stands and the ecosystem dynamics. These variations include

a) dead cover variation with highest density of the Pinus sibirica trees. The ground is almost totally covered by needle litter and very dark. Plant cover of the ground storey is minimal (below 5%) and mostly represented by vaccinium vitis-iadea and mosses; the total biodiversity of these variation is 32 species, but most of them are represented by scarce individuals. We believe it is fully developed high-density stone pine forests.
b) Rocky variation with the large number of petrophytes is forming on the rock outcrops. The primary dominant species here are Bergenia crassifolia, vaccinium vitis-idaea and several moss species. The ground storey cover may reach 50-60%, but biodiversity of the variation is low: only 24 species.
c) Siberian stone pine – moss – cowberry variation is one of the two most common variations which exist in high- and moderate tree density parts of the forest ecosystem. The shade-requiring plants are most common here, but the most important ground storey species here is the *Vaccinium vitis-idaea* which cover 25-75% of the ground and 12-15% of the ground is covered by the mosses. The biodiversity of this variation is 37 species, 5 of the are mosses..
d) Siberian stone pine – cowberry – forbs variation occurs in the light or moderate density areas. Unlike the 3 previous variations it include scarce shrub storey mainly formed from *Betula rotundifolia* and *Lonicera altaica*. The *Vaccinium vitis-ideaea* still present here but only in the shadiest parts and its cover rarely reach 10%. The forbs (including the number of cereals like Calamagrostis obtusata, and Poa altaica) and sedges (mostly *Carex macroura*) cover most of the ground. The biodiversity of this variation is 53 species.
e) Shrub variation forms as a reaction on major disturbances which cause death of part of trees. The tree storey in this variation is scarce; open places are covered by Betula rotundifolia shrub tickets which cover 25-50% of the area. The cereals (mostly *Calamagrostis obtusata* and Poa altaica) are common under the trees. The biodiversity of this variation is 50 species. We believe this variation is temporary, because the Betula rotundifolia is the light-dependent plant and quickly dies in case if shaded. With the growth of the regeneration it will be eliminated and the variation will turn to Siberian stone pine – cowberyy – forbs one.
f) Windows of regeneration is open places of different plant composition is not stable and can change relatively past. They are not an adaptation per se and formed in places where existing stand which settled in the same period of the time is died because of the old age. They are important part of the cyclic sucession which will be described later.

The general biodiversity of the forests is 104 species of the vascular plants [8] and 35 species of the mosses and lichens. This level of biodiversity is solid enough for the high-mountain ecosystems.

The Siberian stone pine forests has a complex way of regeneration based on cyclic succession [8], though the way of regenerations is not uncommon [6]. The cycle starts from the closed forest stage, usually in dead-cover variation, but other variations also may be final. The nature of the forest life cycle assumed the regeneration happens in cluster of similar age trees which die roughly in the same time. While death of several trees usually change variation to shrub one which ends with replacement of the dead trees by new one, the death of the most trees of the cluster (with the exception of younger which was settled during restorative shrub variation existence) cause forming of tree-less window of regeneration which tend to have significant size (thousands of the square meters) , filled with fallen dead trees. The shade-requiring species of ground cover are quickly replacing by light-requiring meadow species and shrubs, forming the open window of regeneration stage. The forbs are most common here. The most common species are *Calamagrostis pavlovii, C. obtusata*, *Carex macroura, C. semperivrens,* F*estuca altaica, F. ovina, Poa altaica,* and the *Bergenia crassifolia* in the rocky places. The shrubs (mostly Betula rotundifolia, Salix sajanensis and Juniperus sibirica) are colonizing the open window turning it to the closed window stage. The area covered by V*accinium vitis idea* greatly reduces. The young Pinus trees whose growth now is not suppressed by large trees begin their growth and quickly form the sparse stand stage. It includes a number of thing young trees. With the tree growth shrub comonsition is changing to more forest like, Betula routnidlia are replacing by Lonicera altaica, forbs composition also changes to forest like, with domination of Calamagrostis obtusata, Poa altaica and mostly *Carex macroura.* The vaccinium vitis-idaea proliferates again. Finally the sparse stand stage turns to Siberian stone pine – cowberry – forbs variation which van later develop to densier stages. The time which is required for the succession may be different, because of weather fluctuations and climate changes. We assume that during the colder periods the number of closed windows of regeneration increases and when the climate allows their colonization by the Pinus sibirica they are colonized almost simultaneously what in the larger scope cause forming of the distinctive tree generations.

The replacement of the Siberian stone pine forests which were destroyed in the mid XIX century by the Siberian larch demonstrate the low resilence of these forests which cannot quickly recover themselves after the major impacts, but the larch forest surrounding Siberian stone pine massifs contain a number of areas with twin tree storey: the upper one consist of a a somewhat scarce high larch trees and the lower one of much younger Siberian stone pine trees; many other areas contain *Pinus sibirica* undergrowth.

CONCLUSION

The old-age forests of the Altai are the rare examples of the ecosystems which is almost not affected by human activities; some parts of these forest are completely unaffected. They represent rare example of purely wild nature which allows to study ecosystem as they are, as a part of the unaffected by human nature, as a kind

of reference for other ecosystem studies. These forests are very stable and stress-proof ecosystems, though their resilence as ability to recover after major disturbances are limited and this fact is the major risk for these forests.

The stability of this forests is high because they are able to endure the signigicant stresses, including (to some degree) climate changes: the ecosystems outlived both medieval warming and Little Ice age. Such impressive stability is mainly formed by high ecological amplitude of the *Pinus sibirica*, its longevity, ability to produce seeds until the physical death of the tree, its environment-changing abilities and adaptivity of Siberian stone pine dominated ecosystem.

The studies of such ecosystems are important because their surprising stability is probably higher than many scientists believe. It is probably many ecosystems will be more stable and changes of the Earth biosphere will be less significant than many modern mathematical models suggest.

REFERENCES

[1] Sevastyanov V.V. Climate of the high-mountainous areas of the Altai and Sayan. Tomsk: Publishing House of Tomsk State University, 1998. 202 p. [in Russian].

[2] Kharlamova N.V. Estimation and prognosis of the modern climate changes of the Altai region climate, Barnaul: Altai university publishing, 2013, 156 p. [In Russian]

[3] Krylov G.V., Talancev N.K., Kozakova N.F. Stone pine, Russia, Moskow: forest industry, 1983, 216p. [In Russian]

[4] Timoshok E.E., Timoshok E.N., Skorokhodov S.N. Ecology of Siberian stone pine (*Pinus sibirica* Du Tour) and Siberian larch (*Larix sibirica* Ledeb.) in the mountain glacier basins of the Altai, Russia, Russian journal of ecology, iss. 3, pp 204-211, 2014.

[5] Timoshok E.E., Timoshok E.N., Nikolaeva S.A., Savchuk D.A., Filimonova E.O., Skorokhodov S.N., Bocharov A.Yu., Monitoring of high altitudinal terrestrial ecosystems in the Altai Mountains, IOP Conference Series: Earth and Environmental Science, Vol. 48, pp. 1–9, 2016.

[6] Sukachev N.V., Selected works, Russia, Leningrad: Nauka, vol . 1, 1972, 418 p. [In Russian]

[7] Uranov A.A. Phytogenic field, Russia, Problems of the contemporary botany, vol 1, p. 251-254, 1965. [In Russian]

[8] Timoshok E.E., Timoshok E.N., Raiskaya Iu.G. Biodiversity of the vascular plants in the old-age forests in the Severo-Chuiskiy center of the modern glaciation (Altai mountains. Russia, Successes of the modern natural history, Iss 11(2), p. 289-394, 2018 [In Russian]