

## POTENTIAL GEO-DISTRIBUTION OF *PINUS SIBIRICA* DEMONSTRATED BY CLIMATIC SIMILARITY BETWEEN WESTERN SIBERIA AND NORTHEAST CHINA

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### ABSTRACT

The spatio-temporal distribution of forests is related to climate. *Pinus sibirica* is a native species in areas subject to continental temperate cold climate that favors its growth. This study was carried out with the aim of evaluating the climatic suitability of northeast and northwest China for the introduction of *Pinus sibirica*. For this purpose, climate of the northeast and northwest China was compared with the climate of Western Siberia (Russia). The Climatic data was obtained from NMKI Climate explorer and China meteorological administration. The Tukey Pairwise Comparison test found that Mohe weather station in northeast China shows (-4.7 °C, -3.26 °C, -5.31 °C and -3.9 °C) resemblance in temperature with three of western Siberian stations where *Pinus sibirica* is distributed in association with *Larix sibirica* and *Picea obovata*. The annual mean precipitation for all the weather stations including Mohe and Huma, China was more than 420 – 609 mm. This specie is also found to grow in various elevations in Western Siberia from 45 to 25 m in Altai Mountains, and from 300 to 700 m in Daxing' anling Mountains. In conclusion, climatic regimes in terms of temperature and precipitation in Daxing' anling Mountains allow the introduction of the *Pinus sibirica* into northeast China.

**Key words:** *Pinus sibirica*, Northeastern China, Northwestern China.

### INTRODUCTION

The spatiotemporal distribution of forest trees is directly or indirectly related to climate regimes (Tchebakova, 1994). Low winter temperatures and permafrost are limiting factors that formulate the composition and distribution of plant communities in Siberia (Nazimova *et al.*, 1990; Tchebakova *et al.*, 1994). In the Russian Arctic region, temperature, precipitation, and soil moisture are proven impactful in the distribution of tree species. Low winter temperature and permafrost are crucial limiting factors controlling forest trees distribution under Siberian Continental Climate (Tchebakova *et al.*, 1994). Climatic factors including temperature and precipitation of an area can also affect the hydrology and soil aeration (Mudrik and Vil'chek, 2001).

Siberian forests are mainly composed of 8 conifers, 49% *Larix* species, 13% *Pinus sylvestris*, 7% *Picea obovata*, 6 % *Pinus sibirica*, 2% *Abies sibirica* and 19 % hardwood and other species. Siberian pine (*Pinus sibirica*) and other dark needled conifers dominate the West Siberia, Yenisei ridge, the Altai and Sayan Mountains (Nadezda *et al.*, 2006). Siberian pine is mainly distributed in the western Siberia (mainly in river terraces, depression rather than upland habitats) (Krylov *et al.*, 1983). *Pinus sibirica* is also distributed along the river terraces but never forms pure tree stand. *Pinus sibirica* is

found in a small group of the dense scrub vegetation of *Cotoneaster melanocarpus*, *Sorbus sibirica* and *Padus asiatica* on the coast of Svyatoi Nos isthmus (Anenkhonov and Chytrý, 1998). This specie seems to adapt better than *Pinus sylvestris* to the influence of the high speed cold winds and the cooling effect of fog. *Pinus sylvestris* mostly avoids extreme cold habitats. *Pinus sibirica*, along with *Larix sibirica*, *Picea obovata* and *Abies sibirica*, is widely distributed from the dark coniferous forest of Europe to central Siberia. In Altai, both the north and west facing slope receives relatively high precipitation and experiences low temperature, therefore, many broad-leaved species come under the canopy of *Abies sibirica*, like *Viburnum opulus*, *Daphne mezereum*, and *Asarum europaeum*. *Pinus sibirica*, along with *Larix sibirica*, is found in central Altai (2100 meter above sea level) and dark coniferous taiga with *Picea obovata*, *Abies sibirica* and *Pinus sibirica* at (1985-2050 m) in the northern and southwestern areas (Blyakharachuk *et al.* 2004).

*Pinus sibirica*, also known as “the tree of fog”, is mesotrophic, and is categorised into the ecological group of mesophytes (Kuminova, 1960). It is considered to be frost hardy, relatively hydrophilic and shade tolerant species, primarily distributed in the southern mountains of Siberia, with active temperature ranging from 350 -1500 °C and the duration is 60-80 days. The moisture requirement of the species exceeds 460 mm per

year (Nazimova *et al.*, 1990). *Pinus sibirica* is distributed across different habitats; the elevation range is 2100-2500 m.a.s.l, with the exceptional occurrence along Pur and Taz Rivers where elevation varies from 28 to 91 m and 50-75 m.a.s.l respectively (Mudrik and Vil'chek, 2001; Timoshok *et al.*, 2014). This species can be found with an association with dominant *Larix sibirica*, *Pinus sylvestris*, and *Juniperus sibirica* in the corridor stretching from Ulan Bator to Lake Baikal in the North. The average temperature of the region ranges from 0 to -2 °C and precipitation 250 to 400 mm within the corridor, where conifer forests occurred at high elevations (Khosbayar, 1989; Logatchov, 1989). Theoretically, regions having the same climatic conditions can host the similar flora. Therefore, to evaluate the best region for potential introduction of *Pinus sibirica* to northeast China, we compared the climatic conditions of Mohe and Huma, in northernmost China, with that of the Western Siberia Russia.

## MATERIALS AND METHODS

The study area consists of Western Siberia (Russia), Northwestern China (Altai) and Northeastern

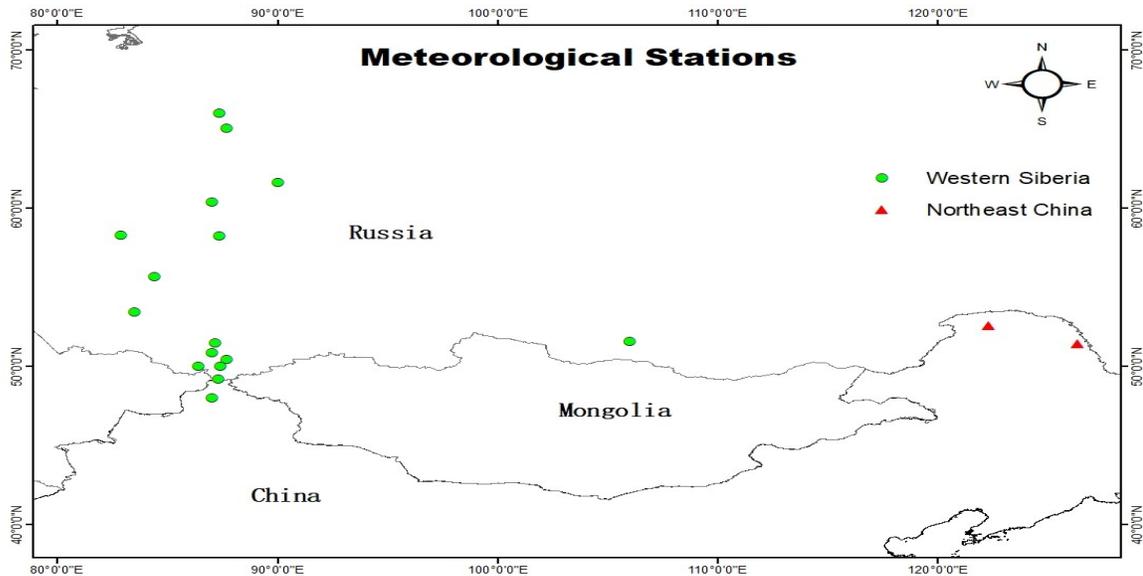
China (Mohe and Huma). Western Siberia comes under the influence of continental temperate climate, experiencing extreme cold winters and warm summers. The area consists of western Siberia e.g. Aleksandrovskoe, Barnaul, Bolotnoe, Kalpasev, Kara Tjurek, Podkamennaja and Tarko. Altai (47.44°N, 88.05°E) mountains is on the south end of western Siberia, and it stretches inside to Northwestern China experiencing the same geographic and climatic conditions (Figure No 1). In northeastern China, Mohe and Huma (52.58°N, 122.31°E and 51.44°N, 126.38°E) have the similar climatic conditions as in western Siberia. Western Siberia is divided into three parts e.g. Northwestern Siberia, Siberian Plains and Southwestern Siberia. The digital elevation model (DEM) was used to find the precipitation and temperature varying through different elevations. The average annual temperature of the Western Siberia is -1.43 °C with 521 mm precipitation per year (Table 1), and in Northwestern China, the average temperature is 2.48 °C with 177 mm precipitation per year. In northeastern China (Mohe and Huma), the average temperature is -2.48 °C with 463 mm annual precipitation (Figure No. 2).

**Table 1. Table showing temperature and precipitation of the Western Siberia, Northeast and Northwest China.**

Country	Meteorological Stations	Average Temperature °C			Precipitation, mm			Coordinates	Years	Elevation (m)
		Year	January	July	Year	June	July			
China	Mohe	-3.91	-28.73	18.37	452	72	96	52.58N 122.31E	30	443
	Huma	-0.37	-24.92	21.02	473.4	73	118	51.44N 126.38E	30	190
	Altai	4.77	-15.25	21.74	177.01	15.95	27.95	47.44N 88.05E	30	868
	Aleksandrovskoe	-1.89	-21.05	17.91	497.7	75.46	81.05	60.40N 77.90E	77	443
	Barnaul	2.2	-15.61	19.91	423	49.98	65.42	53.44N 83.52E	54	288
	Bolotnoe	0.64	-17.71	18.92	491.83	63	68.33	55.67N 84.40E	77	200
Western Siberia	Kalpasev	0.55	-20.19	18.24	465.43	58.4	73.65	58.30N 82.88E	77	71
	Kara Tjurek	-5.32	-16.33	7.02	562.32	78.95	94.32	50.00N 86.42E	73	1759
	Podkamennaja	-3.64	-24.28	17.96	558.58	60.52	67.17	61.60N 90.11E	77	61
	Tarko ale	-5.89	-24.7	19.06	514.63	52.74	61.68	64.92N 77.82E	76	27

Forests are dominated by *Abies sibirica* (Siberian spruce) and *Pinus sibirica* (Siberian pine) on elevated tablelands (Ridge and Yenisei) in Western Siberia and the Southern Altai Sayan mountains. In Altai northwestern China, forests mainly compose of *Pinus*

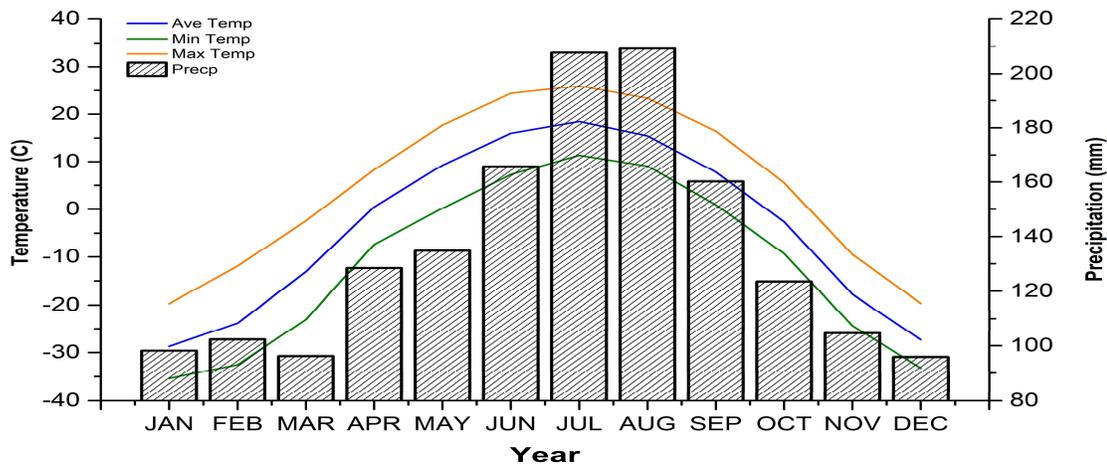
*sibirica*, *Picea sibirica* and *Larix sibirica*. In northeastern China, Daxing' anling mountains, the vegetation is dominated by *Larix gemilli*, and *Betula platyphylla* and *Populus davidiana* have high abundances in secondary forests.



**Figure 1.** The map shows the meteorological stations locations in Western Siberia (Russian), Northeast and Northwest (China). The red square dots represent the current potential distribution site.

A very few individuals of *Pinus sibirica* tree species found in this region. While the Xiaoxing’Anling Mountains (east of Daxing’Anling Mountains) dominated by *Pinus korainensis* in an association with *Picea jezoensis*, *Abies nephrolepis*, *Tilia amurensis*, *Betulacostata*, *Juglans mandshurica*, *Fraxinus mandshurica* and *Populus ussuriensis*. The climatic data for western Siberia was obtained online from KNMI Climate

Explorer website in January 2017, while for Northwestern China and Northeastern China it was downloaded from China Meteorological Administration (CMA) on December 2016. To compare the climatic condition of three different zones, one way ANOVA was performed in Statistix 8.1 software. The significant differences between the means were determined by Tukey’s Pairwise Comparison test at the level of  $p \leq 0.05$ .



**Fig. 2** Monthly temperature in Mohe and Huma, northeast China. The three lines represent bottom are Maximum, Mean and minimum temperature, respectively while the histograms represent precipitation.

### RESULTS

There are many factors required for tree growth and adaptation. Climatic factors like temperature and precipitation are one of the most important factors which directly affect the growth and survival. Higher

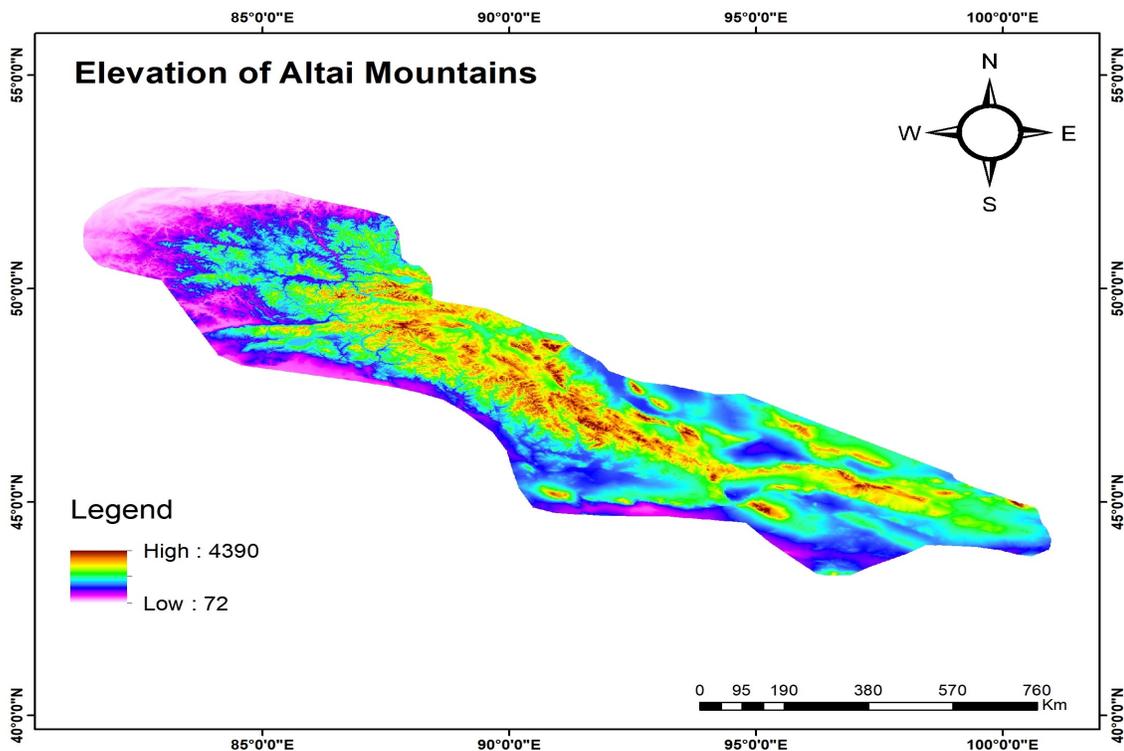
precipitation results in wider tree ring growth while extreme temperatures resulting in narrow tree ring growth and affects the tree growth of a tree species. The comparison of 30-year precipitation and mean temperature of all seven stations from Western Siberia and three from China was carried out.

The elevation also found to be an important factor. The high elevations precipitation and temperature are different from low elevation precipitation and temperature results to different vegetation communities. The high elevations experience extreme low temperature and expose to extreme winds provides an ideal habitat for the survival of the *Pinus sibirica*. The Western Siberia from the north Arctic Ocean to the high peaks of the Altai Mountains at the south consists of various topography from plains to high mountain ranges. The Altai Mountains dominates the southern part of the Western Siberia stretching into northwestern China, eastern Kazakhstan and Western Mongolia (Figure 3). The *Pinus sibirica* dominates the elevation above 1800 m along with *Abies sibirica* and *Picea sibirica*. In northeast China, the Daxing anling mountains elevation ranges to a maximum of 2500 m experiences the continental temperate cold climate. The *Larix gemilli* is dominating the area along with *Betula*. A small population around sixty trees could be found in near the Mangui Country (Figure 4). A small population of this specie gives sign that it was once distributed in the area. The specie can survive in such condition as it has been found in Western Siberia growing well in low elevations of the Altai Mountains in Russia.

**Precipitation:** Sum of the precipitation from ten weather stations was compare, and there was no difference in

precipitation detected for Mohe and Huma where they receive mean annual rainfall of 452mm and 473.53mm (Figure 5a) respectively ( $P \leq 0.01$ ). Mean temperature in Mohe was comparabed with that of three stations (Figure 3a) in Western Siberia including Kara Tjurek, Podkami and Tarko Ale with homogenous group E, DE, E and DE ( $P \leq 0.005$ ). The mean rainfall of Mohe was not consistently similar to Kara Tjurek, Podkami, and Tarko ale of Western Siberia.

**Temperature:** The weather stations from Russia was compared with the two stations of northeast China, Mohe and Huma. The similarity in temperature ( $P \leq 0.005$ ) was analyzed among three stations of Western Siberia including Barnaul (A), Bolotnoe (AB), Kalpsev (ABC) with Altai (A), China. High similarity of mean temperature was confirmed between Mohe (Northern China) and Podkami (Western Russia); the mean temperatures were  $-3.9\text{ }^{\circ}\text{C}$  and  $-3.26\text{ }^{\circ}\text{C}$  respectively. Statistically, stations labelled same (Mohe and Podkmi both have Label E) have high similarity in mean temperature (Figure 5b). The weather station Huma is having a mean temperature of  $-0.36\text{ }^{\circ}\text{C}$ , showing little similarity with other weather stations. The variation in mean temperature is due to their location from each other and also the permafrost occurrence in some areas. Some extreme low temperatures are due to high elevations, e.g. 2500 m a.s.l., where weather stations are located.

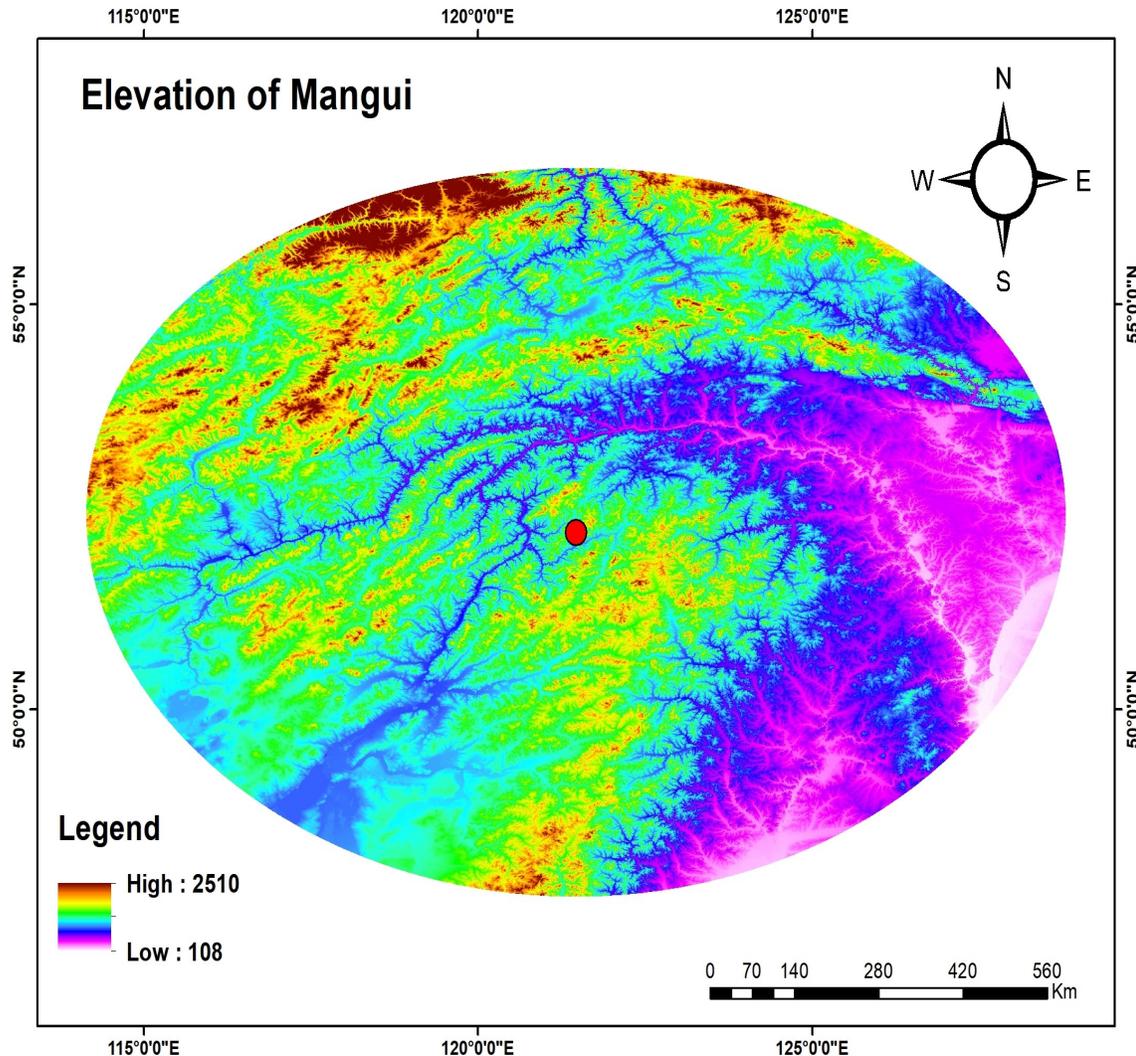


**Fig. 3** The figure showing the Altai Mountains range stretching from the Russian Altai to northern Kazakhstan, western Mongolia and northwestern China Altai mountains. The high elevation dominated by *Pinus sibirica*, *Abies sibirica* and *Picea sibirica*.

## DISCUSSION

In this study we compared the temperature and precipitation of three weather stations in northeast China including Mohe, Altai and Huma with seven weather stations in Western Siberia (Alesksandrovoskoe, Barnaul, Bolotnoe, Kalpasev, Kara Tjurek, Podkamennaja, Tarko ale) to evaluate the most suitable region (in northern China) for the introduction of *Pinus sibirica* on the basis of climatic similarities. Main interest was to find out the

similarity in temperature and precipitation of Mohe and Huma to that of Western Siberia. Mean temperature and mean precipitation in Mohe showed similar with that of the three weather stations in Western Siberia including Kara Tjurek, Podkami, and Tarko ale. Our results revealed that mean temperature in Mohe (Northern China) was highly similar to that in Podkami (Western Russia), both having mean temperatures of -3.9 C and -3.26 C, respectively and statistically grouped as DE Figure 3(a).



**Fig. 4** The figure showing the elevation of northeast China Mangui County. The Red spot showing the current distribution of *Pinus sibirica*.

It is expected that by mean temperature similarities, Mohe can be a potential habitat for *Pinus sibirica*. There is a sporadic population of *Pinus sibirica* also exists in Daxing'angling Mountains of Inner Mongolia, with a distance of just 98 km from Mohe, under the influence of continental climate having harsh winter and high wind velocity. Daxing' anling Mountains

span over an area of 10.66 million hectares. The elevation range of these mountains is 425-1760 m.a.s.l, which is similar to that of Western Siberia (Russia) where the species are present (Meng *et al.*, 2017). The temperature of the Daxing' anling Mountains statistically indicated resemblance with other parts of Western Siberia where *Pinus sibirica* primarily occurs.

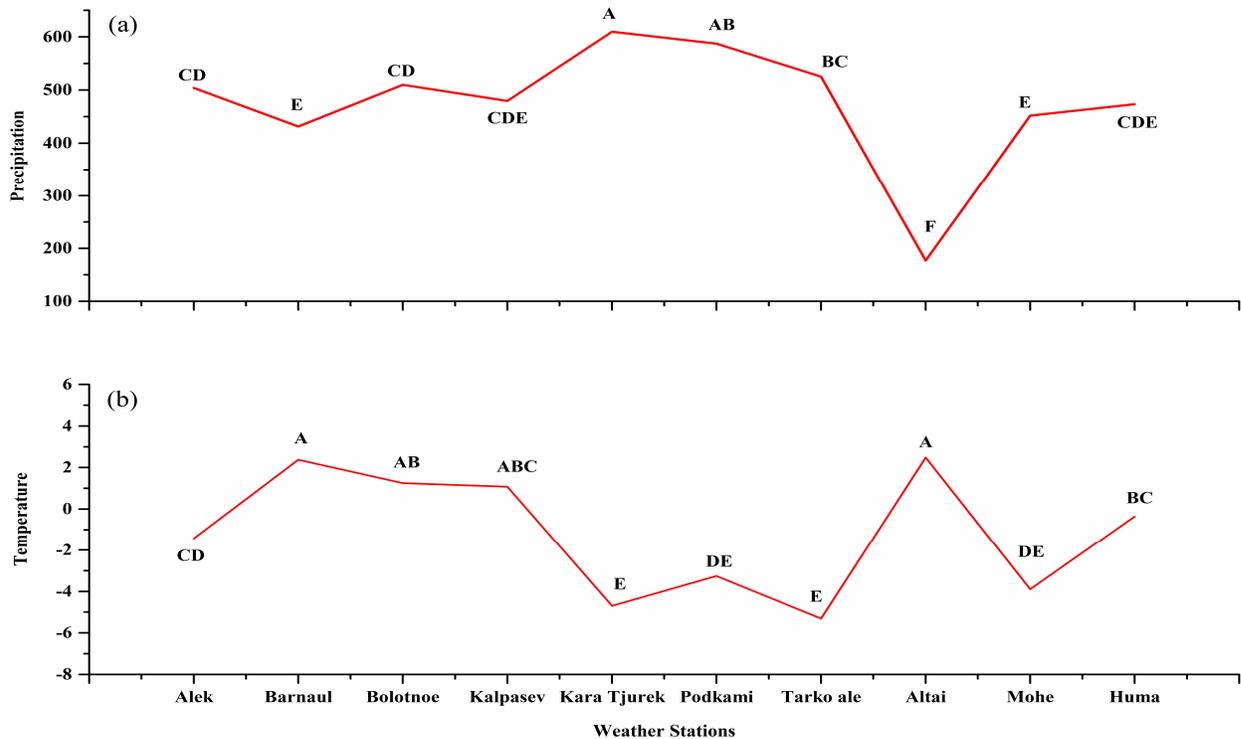


Fig. 5(a) Stations with the same labels present high similarity in precipitation, e.g. Mohe (E) has high precipitation similarity with Barnaul (E), moderate similarity with Bolotnoe (CD), Alek (CD), Kalpasev (CDE) and Huma (CDE), while Fig. 5(b) Stations with the same labels present high similarity in temperature regimes, e.g. Mohe (DE) has a high similarity with Podkami (DE), moderate similarity with Kara Tjurek (E) and Tarko ale (E).

Many forest conifers of the northern hemisphere have been successfully introduced to Patagonia and New Zealand (Jobbágy and Jackson, 2000). Huma was not found similar to any sites of the Western Siberia regarding mean temperature. For precipitation, there was a high similarity between Mohe and Barnaul, although mean temperatures of both stations were very different. Mohe and Podkami were highly similar in mean temperature, but different in mean precipitation since Mohe receives very low precipitation as compared to Podkami. Siberian pine is less effected by precipitation, as it is found in various regions of Western Siberia, experiencing a wide range of precipitation (Agafonov *et al.*, 2004; Tchebakova *et al.*, 2009). A previous report (Kharuk *et al.*, 2013) stated the species in association with dominance *Larix sibirica* in the Kuznetzky Altai Mountains, Siberia, where receive annual precipitation of 562mm and the elevation range is 600-1300 m.a.s.l. The species is also documented in Severo Chuisky and Tuva in northwestern Altai in association with *Larix sibirica*, *Picea obovata* and *Abies sibirica*. These forests have an elevation range of 2150-2400 m.a.s.l, and receive annual precipitation of 563 mm with an average temperature of -5.2 °C (Blyakharchuk *et al.*, 2004; Timoshok *et al.*, 2014).

In Daxing' anling Mountains, the species is found in a forest dominantly covered by *Larix gemilli*

(60% in density), accompanied by *Betula platyphylla*, *Pinus sylvestris* and *Populus davidiana*. These mountains could be a potential habitat for introduction of *Pinus sibirica* because it grows well in association with *Larix gemilli*, a dominant species of this area. Researchers traditionally use climatic variables to explain the spatiotemporal distribution of plant species. Understanding the relationship between microclimatic factors and landscape features could be very helpful for conservation and management of tree species and ecosystems (Chen *et al.*, 1996). Temperature and precipitation are among a series of environmental variables that help understand species distribution and habitat selection. They influence the ecological processes like plant growth and regeneration, nutrient cycle, wildlife habitat and soil respiration (Perry, 1998) that are important components of today's ecological research. Distribution of a plant species is synthetically regulated by climatic factors including temperature, precipitation and wind speed (Wachob, 1996).

Highly significant similarity was determined regarding mean temperature in Altai (northeast China) with different regions in Western Siberia including Barnaul, Bolotonoe and Kalpsev. The snow-covered Altai Mountains in Chinese side stretch from the Russian Altai. *Pinus sibirica* is known to occur in Altai

Mountains along with other species including *Larix sibirica* and *Picea obovata* (Tchebakova *et al.*, 2009). Although it was found no similarity in mean temperature between Altai and Mohe, and high similarity in precipitation ( $P \leq 0.0005$ ) was detected between Barnaul (431.57 mm) and Mohe (452 mm), which was interestingly similar with the Altai in temperature.

**Conclusion:** Climatic factors like temperature and precipitation are the important drivers affecting the tree growth. Our study showed a significant relationship for temperature and precipitation of Mohe (northeast China) with that of different other regions (Podkamennaja, Kara Tjurek, Tarko ale, Barnaul and Kalpasevo) in Western Siberia. As the regions above shared a similar climate, therefore, Mohe and some northern parts of Daxing'anling could be a suitable region for the introduction of *Pinus sibirica* in Northeast China. Further comparative studies including (carbon stocks, soil profile etc.) are recommended to evaluate the suitability of Daxing'anling Mountains (Mohe region) for the possible introduction of *Pinus sibirica*.

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