EFFECT OF TEMPERATURE AND PRECIPITATION ON STEM BIOMASS AND COMPOSITION OF WHITE BIRCH (*BETULA PLATYPHYLLA*) IN DAXING'ANLING MOUNTAINS INNER MONGOLIA, CHINA

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Abstract. Forests play a major role in the regional and global carbon cycle. Climate change events have become serious issue, forests from various geographical regions have different sensitivities to climate variation. Therefore, we examine the effect of annual precipitation and annual temperature from 1950-2016 of white birch (Be*tula platyphylla)* stem biomass and composition in Daxing'anling Mountain Inner Mongolia China. We conduct a field survey, a total of 27 plots were established as the research area. In this study, we used allometric equation including the following components: diameter at breast height (DBH) and tree height (H). Our result showed that the response of *Betula platyphylla* stem biomass has a strong correlation with annual precipitation ($R^2 = 0.80$), and with temperature ($R^2 = 0.75$). A positive correlation was found for height with annual precipitation ($R^2 = 0.76$) and annual temperature ($R^2 = 0.51$). Additionally, a slightly positive correlation was observed for density with annual precipitation ($R^2 = 0.26$) and annual temperature ($R^2 = 0.20$). Our results also predicted that competition for survival played a significant role in tree growth. To achieve fast tree growth and high stem biomass response, systematically based forest management strategies, including thinning operation and selective cuttings could be established even under harsh Mongolian weather conditions. Our finding could suggest forest management guidelines for the normal growth of *Betula platyphylla* forest.
Keywords: *Betula platyphylla, stem biomass, forest ecosystem, global warming, carbon stock*

Introduction

Understanding the prediction and response of forest ecosystem to climate change is a crucial challenge for scientists worldwide (Pan et al., 2013). During the last decade, most studied forest ecosystem characters are the tree biomass and carbon storage. The knowledge of the forest distribution is an essential feature for the conservation strategies, including the reduction of global warming by carbon store in forest ecosystem (Saatchi et al., 2011; Baccini et al., 2012). To study boreal forest is particularly important because they store 460 billion tons of carbon in their biomass and soil, which is equal to the total atmospheric carbon stock (Pan et al., 2011), and process 40 billion tons of carbon annually (Beer et al., 2010). Because they cover a large area of land and play an important role in global climate, regulating energy balance and evaporation at the earth. Inverse modeling of biomass and carbon sink sources from the latitudinal distribution of atmospheric carbon dioxide concentration indicates that a major terrestrial carbon sink is located in ecosystem of the northern hemisphere (Tans et al., 1990; Menon et al., 2007) and also believed that significant fraction of this carbon sink occurs in the northern boreal forest (Hyvönen et al., 2007). Boreal forests also contribute to the diversity, richness, productivity in Daxing'anling Mountain in Inner Mongolia China, which exists under a wide range of harsh environmental conditions (Fang et al., 2012). Recently, boreal forest to sequester a substantial amount of atmospheric carbon dioxide and store carbon in its biomass has focus attention from worldwide (Kasischke, 2000; Donato et al., 2011; Alongi, 2014). A recently conducted study on *Larix gmelinii* and *Betula platyphylla* suggested that stem biomass have a strong correlation with annual precipitation and maximum temperature (Khan et al., 2019).

Northern Mongolia Daxing'anling Mountains is the transaction zone between Siberian taiga and Asian steppes. This line of transaction takes place over several hundred kilometers from north to south (Walter, 1974). The climate of this region is strongly seasonal, characterized by short mild summers and long very cold winter with annual precipitation and temperature variation (Korpela et al., 2013). More than 90% annual precipitation fall as rain during the growing season and another hand annual temperature in Mongolia increased by 2014 ◦C from last 70 years, which is higher than the rise of global average temperature. Precipitation almost decreases in every region at least 0.1 mm/year (Oyuntuya et al., 2015). Further decreasing of precipitation is expected in inner mountains (Sato et al., 2007). Current climate change, is considered the main driver of the vegetation change and observation showed that regional climatic variation has resulted in change in the natural and biological system, such as snow melting and the extension of growing season in the mid-high latitude areas (Douville, 2006; Shea et al., 2015; Rangecroft et al., 2016). Forest degradation significantly impact carbon stock (Baccini et al., 2012), and the recent climatic trend is already impacting forest biomass worldwide (Phillips et al., 2009). Recent studied describe that precipitation and temperature influence the forest ecosystem. Such as a change in temperature and precipitation is directly associated with global warming (Hidalgo-Muñoz et al., 2011; Coumou and Rahmstorf, 2012; Coumou et al., 2013; Omondi et al., 2014). During the last decades, due to the change of precipitation and temperature, many forest sites are replaced by steppe vegetation, while the composition of remaining species changes in the favor of pioneer tree species. Therefore, regeneration of different species increase their interest, while the effect the growth of the native tree species such as white birch (*Betula platyphylla)* (Dulamsuren et al., 2011; Khishigjargal et al., 2014; Gradel et al., 2017). *Betula platyphylla* growth pattern relationship with climate change is also useful for the forecast of species distribution and forest productivity (James, 2011; De Grandpré et al., 2011).

Betula platyphylla was also known as, Manchurian birch or Asian white birch. *Betula platyphylla* is one of the common tree species in Daxing'anling Mountains Inner Mongolia. This species is drought sensitive, have good resistance against frost and able to grow under different climatic condition (Gradel et al., 2017). *Betula platyphylla* had good economic value and its height can reach up to 27 m along with the life duration of 140 years (Zyryanova et al., 2010). It is also one of the pioneer tree species from the south forest outposts in Inner Mongolia. Still, it is the most dominant tree species in the forest instead of human disturbance, cutting and use is a fire due to its fast sprouting capability (Otoda et al., 2013). It is important to protect this species to maintain their forest cover because of its play a significant role in biomass storage as we as in carbon sequestration potential (Hansen et al., 2013). Numerous approaches examine to understand forest biomass. Some are based on a comparison of remote sensing data with standing variables, such as diameter, height, and density to estimate above-ground biomass of trees (Baraloto et al., 2011). This type of correlative studies provide spatially explicit and to verified the estimate the above-ground biomass for an extensive assessment of carbon stock (Saatchi et al., 2011). This method has great importance for mapping carbon stock and evaluating risk from land-use change, which is beneficial for policy involvements (Asner and Mascaro, 2014).

Therefore, allowed the author to investigate the effect of climatic factors and stand characteristics of stem biomass allocation pattern of *Betula platyphylla* species. Although the dataset of China has used to evaluate the temperature effect on biomass allocation in the forest (Lie and Xue, 2016). While data about the effect of climatic factors on stem biomass and composition of *Betula platyphylla* forest is still lacking. Therefore, we want to find out the relationship between climatic factors such as precipitation and temperature from 1950-2016 with *Betula platyphylla* stem biomass. We also want to examine the influence of climatic factors on the height and density of Betula platyphylla.

Material and methods

Study area

Daxing'anling mountains are located at (E'7118.19.10-W'126.41.52, N'47.48.35-S53.33.12) in the Heilongjiang province of China which cover the area of 83000 km^2 with an altitude of 3556 m (*Figure 1*). This area has cold continental monsoon weather with an annual temperature of 2.8°C. Annual precipitation mostly received in July to August from 350-500 mm. snow covers the land for five months in the winter season, which have depth up to 30-50 cm in the forest area with wind flow of 1106 miles per hours. *Betula platyphylla* is the dominant tree species along Dahurian larch (Larix gmelini), Scots pine (Pinus sylvestris var), Mongolian oak (mongolica) among others are common tree species. During the months of summer from April to July of each year usually occur thunderstorms, lightning fires which become a cause burning to this area.

Field data collection

To take forest data a field survey was conducted in 2017 in Daxing'anling mountain of Inner Mongolia Autonomous Region of China. We used a random sampling method and a total of 27 circular plots was taken in the study area. Each selected sampling plot have a radius of 17.84 m. To find out stem biomass and carbon stock of *Betula platyphylla* stand forest, tree diameter at breast height (DBH), tree height (H) and Density (D) were measured in the study area.

Climatic data collection

Climatic factors, such as annual precipitation and annual temperature from 1950 to 2016 were chosen as the parameters in the study area of Daxing'anling Mountain Inner Mongolia, China (*Figure 2*). Data of annual precipitation and annual temperature were download from the (0.50) grid data with help of KNMI climate Explorer [https://climexp.knmi.nl]. The climate station was uniformly distributed in northeastern Inner Mongolia China. Climatic data of each sample plot was download from its coordinate using a global positioning system (GPS) with an accuracy of 1-meter distance. It is used to extract the geographical data of each sample plot. Climate record has been assessed by China metrological administration (CMA) to assure consistency with continuity and to maintain the quality of instrument location and relocation of the stations.
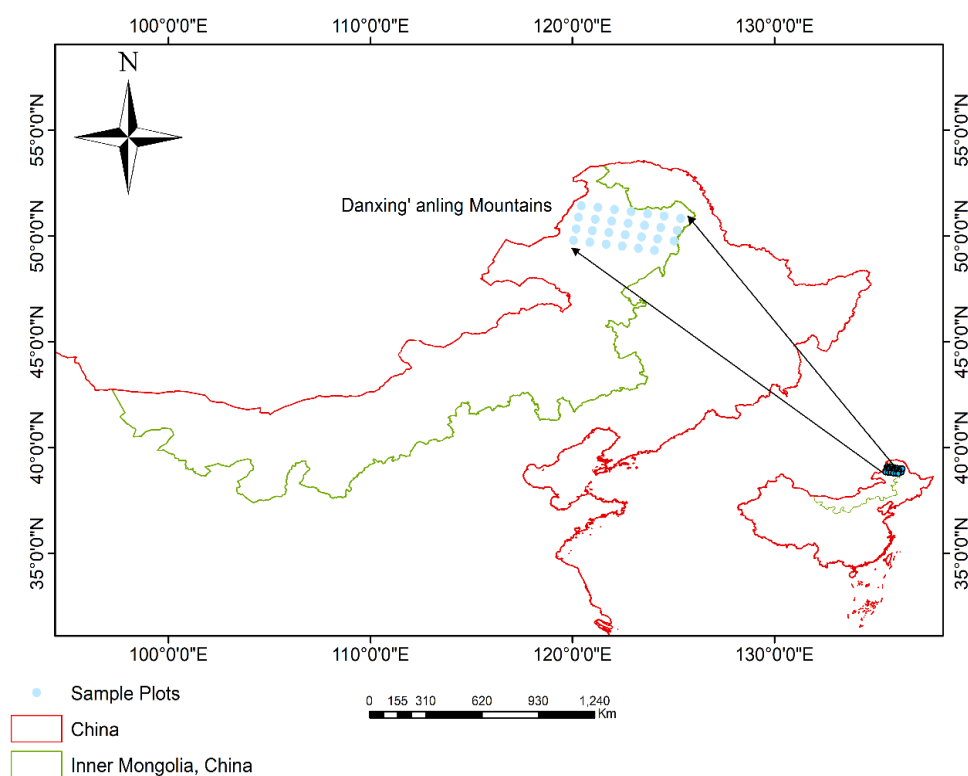

Figure 1. *Geographical Mapping of the study area. Map showing the geographic location of Betula platyphylla plots in Daxing'anling Mountains Inner Mongolia, China*

Stem biomass estimation

Several allometric equations have been developed by researchers to estimate biomass of different tree species using several variables as predictors or independent variables. DBH, total height, volume, basal area, density, and crown radius are the common variables used for estimation of tree biomass (Chave et al., 2005; Mandal et al., 2013; Goodman et al., 2014). The allometric equation gives us a result of the linear and nonlinear correlation between variables in two dimensions (Picard et al., 2012). The quality of the allometric equation is necessary for ensuring the accuracy of forest biomass estimation. It is not only the matter of error but also a statistical toll during the

process should be considered (Picard et al., 2012). Stem biomass should be measured from the recommended component such as diameter at the breast height and height of the tree (H) (Chave et al., 2006). A model is considered reasonable if it yields estimates with minimum standard error (SEE), the minimum sum of the square of the residual error (SSE) throughout the range of data, does not give negative estimates and does not show a decrease in biomass with an increase in diameter or height (Ali et al., 2016).

The following allometric equation was used for *Betula platyphylla* to find out stem biomass and carbon stock which is developed by (Cheng and Li, 1989).

$$Ws = 0.1193 \ (D2 \ H) \ 0.8372 \qquad \text{(Eq.1)}$$

To estimate the stem biomass having a coefficient of determination of (R^2) of 0.1193. Where (Ws), is the stem biomass, tree diameter at breast height (D) and tree height (H). To find out total stem biomass per plot was summed for all plots and average to get the mean stem biomass, which was then converted to tons per hectare. Biomass fraction analysis was used to convert the value to its carbon equivalent. Carbon stock was determined as the product of the carbon sink and corresponding biomass of the individual tree.
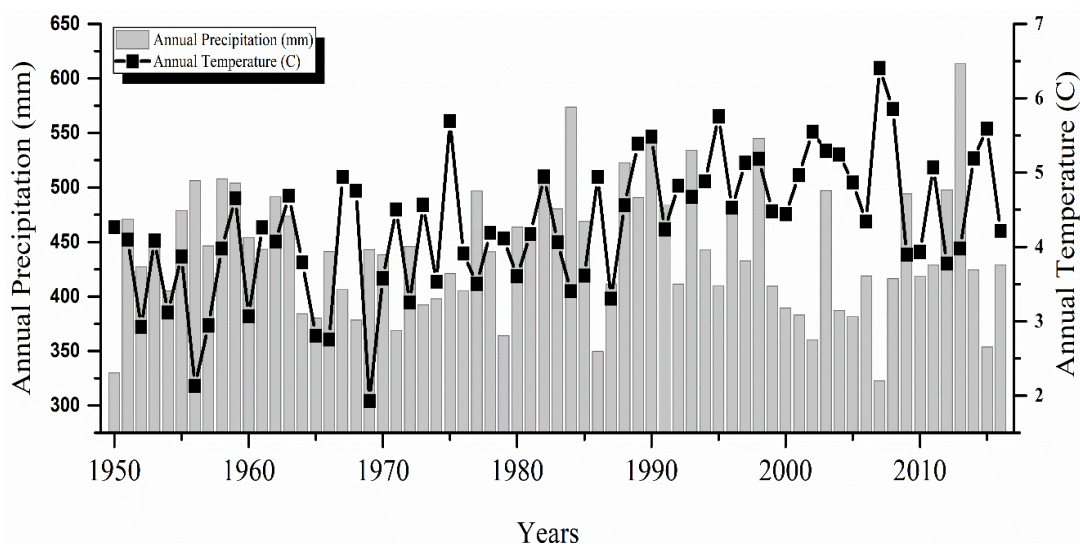

Figure 2. *Yearly climate diagram. Yearly climate diagram of annual precipitation and annual temperature from 1950-2016 in Daxing'anling Mountain Inner Mongolia, China*

Statistical analysis

Regression analysis was performed between dependent variables like stem biomass and carbon stock with explanatory variables like diameter, density, height and climatic variables Such as annual precipitation and annual temperature. The coefficient of determination (R^2) and probability level ($p \leq 0.05$) was used to determine the quality of curves. To check the variables relationship accuracy, we used linear regression analysis to check the variables relationship accuracy. All statistical analysis Analyses were performed using Origin-2016.

Results

The growing stock of Betula platyphylla

Betula platyphylla is the second most dominant species of Daxing'anling Mountains Inner Mongolia China, instead of human's disturbance, cutting and fires, due to its sprouting capability. The result revealed that average stem density ranged from 71.7 ± 21.6 (trees ha^{-1}) while, the total range between low to high stem density was 34.0 ± 111.0 (trees ha^{-1}). The mean diameter of the tree was in the range of 16.3 ± 3.3 (cm) to 11.4 ± 23.8 (cm). The value of average height ranges from 20.8 ± 4.49 (m) to 14.0 ± 29.0 (m), (*Table 1*).

Table 1. *Growing stock characteristics of Betula platyphylla*

No	*Betula platyphylla*	Average density	Average diameter	Average height
1	Mean & Standard deviation	71.7±21.6	16.3±3.3	20.8±4.4
2	Minimum & Maximum	34.0±111.0	11.4±23.8	14.0±29.0

In order to study the relationship between stem biomass (ton/ha), height (m), density (ha^{-1}) with annual precipitation (mm) and annual temperature (^{0}C) regression models were developed in detail which is given below in (*Table 2*).

Table 2. *Relationship type, equation and R^2 value of the Betula platyphylla stand*

Climatic factor	Parameters	Relationship type	Equation	R^2 Value
Precipitation	Stem biomass	Polynomial, Linear	y = -115.9592+ 0.6129*x	0.8014
	Height	Polynomial, Linear	y = -21.9297 + 0.1015*x	0.7674
	Density	Polynomial, Linear	y = 81.8608+ 12.4413*x	0.0696
Temperature	Stem biomass	Polynomial, Linear	y = 81.8608+ 12.4413*x	0.7562
	Height	Polynomial, Linear	y = 12.4017 + 1.7366*x	0.5144
	Density	Polynomial, Linear	y = 54.3686 + 3.5805*x	0.0921

Relationship of precipitation (mm) and temperature (^{0}C) with stem biomass (ton/ha), height (m) and density (ha^{-1}) of *Betula platyphylla*

Biomass and carbon stock of Betula platyphylla with climatic factors

Total tree biomass distribution of *Betula platyphylla* forest was recorded at a range of 142.2±26.2 (ton/ha) with, variation from minimum to maximum 26.2±188.3 (ton/ha) was absorbed. While the total average stem biomass 142 (ton/ha) were found. Carbon stock recorded at the range of 68.7 ± 23.0 to 23.0 ± 134.4 (ton/ha) with, total average carbon stock of 71 (ton/ha) in the study area. The total average precipitation 421 (mm) recorded with the range of 421.2±38.3 along, variation from minimum to maximum 38.3±490.0 mm. The temperature range was 4.9±1.8 to 1.8±134.4 (^{0}C) with a total average temperature of 5 (^{0}C), which are given in the following (*Table 3*).

Effect of climatic factors on stem biomass, height, and density of Betula platyphylla

To study the influence of climatic variables such as annual precipitation and annual temperature from 1950-2016 on stem biomass, height and density of *Betula platyphylla* in Daxing'anling Mountains Inner Mongolia. Annual precipitation and annual temperature have a positive correlation with *Betula platyphylla* stem biomass and height. While a negative correlation was absorbed with a density of *Betula platyphylla*.

According to coefficient correlation (P≤0.05), the result showed that annual precipitation (R^2 = 0.80) and annual temperature (R^2 = 0.75) have the strongest correlation with stem biomass (*Figure 3*).

While, height have strong correlation with annual precipitation (R^2 = 0.76) and annual temperature (R^2 = 0.51), respectively (*Figure 4*).

Table 3. *Biomass and carbon parameters with climatic variables of Betula platyphylla*

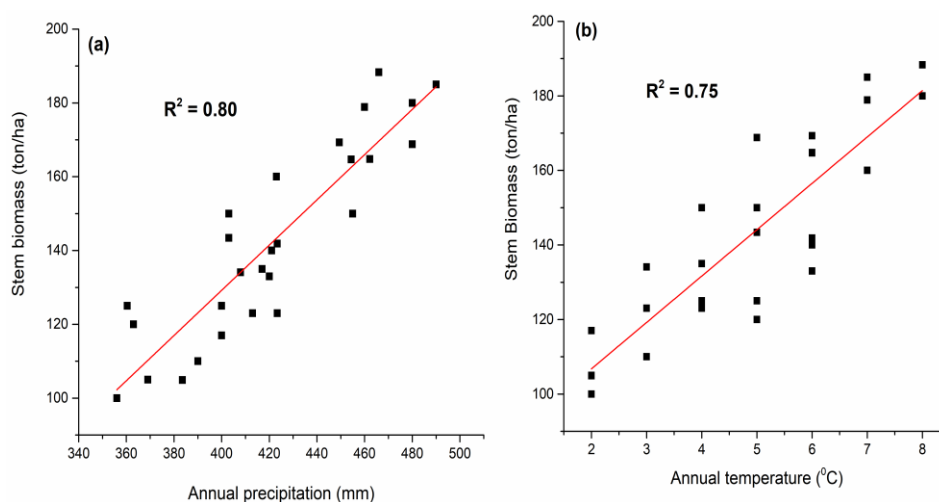| *Betula platyphylla*	Mean & Standard deviation	Minimum± Maximum
Stem Biomass	142.2±26.2	26.2±188.3
Carbon Stock	68.7±23.0	23.0±134.4
Precipitation	421.2±38.3	38.3±490.0
Temperature	4.9±1.8	1.8±134.4

Figure 3. *Stem biomass correlation with annual precipitation and temperature. Betula platyphylla stem biomass correlation with Annual precipitation (a) and Annual temperature (b) from 1950 – 2016*
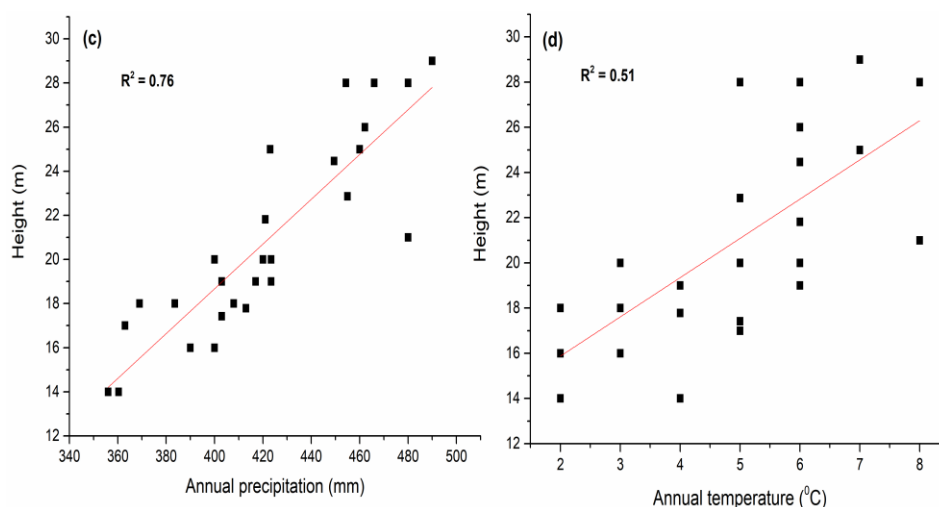

Figure 4. *Height correlation with annual precipitation and temperature. Betula platyphylla height correlation with Annual precipitation (c) and Annual temperature (d) from 1950 – 2016*

In addition, slightly positive correlation was found between *Betula platyphylla* density with annual precipitation ($R^2 = 0.26$) and annual temperature ($R^2 = 0.20$) (*Figure 5*).
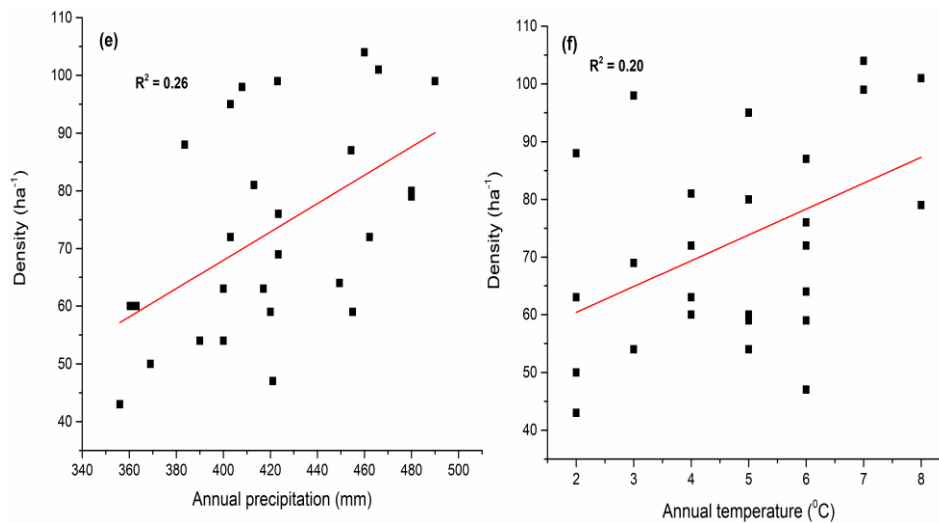

Figure 5. *Density correlation with annual precipitation and temperature. Betula platyphylla density correlation with Annual precipitation (e) and Annual temperature (f) from 1950 – 2016*

Discussion

Daxing'anling Mountains of Inner Mongolia is the important region of northern China. It is located at the high latitude of the northern hemisphere. Which is considered the most sensitive zone to global climate change (Dai et al., 2002; Wang et al., 2012). *Betula platyphylla* forest of this region plays a key role in the contribution of global carbon flux (Wang et al., 2006; Cai et al., 2015), as well as, in the establishment of forest lands consequent harvest and wildfires (Wang et al., 2015). It holds 8.39 million hectare of forest land and 0.76 billion m^3 of timber stock, respectively (Fang et al., 2001; Wang et al., 2006). Wide distribution with transaction character from boreal to the temperate zone, make it important in its prime production and carbon sequestration potential (Wang et al., 2006, 2008). Boreal forests in Inner Mongolia also have tremendous carbon storage mainly due to their vast forest area and living wood stock volume, though their coverage and carbon density lag behind many other provinces in China. Thus, as a whole, they play a significant role in the Chinese terrestrial ecosystem carbon cycle and in turn play an important role in the global carbon cycle (Sun et al., 2008). Meanwhile, there are many challenges as well as opportunities for a long-time forest in the area is lack of management with the extensive degradation of existent stands and poor stand quality and low productivity. The aggravation of desertification accompanying warming and drying trend under climate change is a huge threat to the forests.

Forest vegetation under different climate conditions reacts with a different way to their climatic factors. Climatic variables assessment of the last 66 year annual precipitation and annual temperature predict positive correlation with *Betula platyphylla*. *Betula platyphylla* stem biomass has a strong correlation with annual precipitation ($R^2 = 0.80$), and annual temperature ($R^2 = 0.75$). While, positive correlation was found

for height with annual precipitation ($R^2 = 0.76$) and annual temperature ($R^2 = 0.51$). Forests response positively to the impact of rising precipitation and temperature (Fang et al., 2003; Piao et al., 2005), and they have a positive effect on forest biomass (Lindner et al., 2010). Increase in precipitation and temperature will increase the absorption of carbon dioxide in the forest vegetation (Grant et al., 2004). In term of, stand age had an influence on forest carbon storage. Increasing of stand age also increase carbon storage capacity (Yu et al., 2017). At last, at last, the carbon storage in the forest decreases to a relatively stable level, due to the limiting of hydraulic resistance (Zaehle et al., 2006), and the growth of wood become very slow, which is almost not change (Liu et al., 2012). Some studies also predicted that precipitation and temperature are the main climatic factors that affect forest vegetation in the mid-western United States and China (Peckham et al., 2012), Russia (Alexeyev et al., 1995), Canada, and the Netherlands (Nabuurs and Mohren, 1993) among other places. While the response of vegetation types to precipitation and temperature has differed among places. The rising of precipitation and temperature have been found to increase the forest biomass in colder and wetter ecoregions (Dymond et al., 2015), but reduce the net rate of stem biomass in the Amazon rainforest (Brienen et al., 2015), and the growth rates of mature rainforests (Hopkin, 2007).

Additionally, the results showed that precipitation and temperature were significantly affected by plant density. Due to which the response of density of *Betula platyphylla* has a slightly positive correlation with the annual precipitation ($R^2 = 0.035$) and annual temperature ($R^2 = 0.09$), Similarly to the previous studies on tropical elevation transect forest (Leuschner et al., 2007; Girardin et al., 2010). Increase in plant density creates the interplant competition over light and precipitation which cause the disturbance in the balance of growth regulators. Under these conditions, plant density increases while, decrease in light and precipitation penetration into middle and lower layers of canopy and auxin decomposition (Imam and Ranjbar, 2000). Increase in plant density had a significant effect on *Betula platyphylla* plant height. Which tends to decrease because the plants compete over other growth affecting parameters than light (Mukhopadhyay and Sen, 1997).

Generally, denser *Betula platyphylla* stands forest results in higher total production, but the growth of the individual trees will be small (Ohtsuka et al., 2005). The increased volume production can though easily be lost through damages caused by wind or snow (Nykänen et al., 1997). With an increased number of stems density, the dimension decreases, while the volume concentrates in weaker dimensions (Coomes and Allen, 2007). The utility of wood products will be increased with lower stem densities (King et al., 2006). When pre-commercial thinning is performed competition for light and nutrition will decrease and the single stem will have the possibility to increase its diameter growth (Pothier, 2002; Karp and Shield, 2008). The main role of *Betula platyphylla* Silviculture is to have dense stands initially and then successively widening the spacing between the stems (Almgren, 1990). The green crown should never be smaller than half the stem length (Lapidge et al., 2000; Hörnfeldt, 2014). Since shad intolerant species like *Betula platyphylla* has a strong relationship between tree crown diameter and growth (Dolezal et al., 2004). *Betula platyphylla* stands with less than 50% of the living crown will have a small possibility to respond positively to future thinning (Dolezal et al., 2004). Thus, other stand variables such as height, diameter, and stem biomass could be important parameters to driving this observation,

however, the data of wood density in mountain forests is infrequent and requires more sampling effort (Chave et al., 2009).

Demonstrating to find out stem biomass quantification in the *Betula platyphylla* forest in Daxing'anling Mountain. The destructive sampling method was not possible in our study site. That's why we attempt to minimize the uncertainty, we used the allometric equation developed in a similar climate condition with similar tree composition (Cheng and Li, 1989). In general tree diameter at the breast height and height of the tree is commonly used is a parameter to find out tree biomass in most equations (Wang, 2006; Dong et al., 2014; Wang et al., 2017). Furthermore, its depend on research goals and three components to investigate tree biomass with the help of equation (Zou et al., 2015; Kralicek et al., 2017).

Thus, during 1950–2016, the response of stem biomass and height of *Betula platyphylla* forest have a strong correlation with annual precipitation and annual temperature. While density has a negative correlation. That's mean, it also needs further research on forest management and the relative contribution of human activities to forest vegetation in Inner Mongolia.

Conclusion

In this study, we examined the effect climate factors, such as precipitation and temperature from 1950-2016 on *Betula platyphylla* forest ecosystem in Daxing'anling Mountains Northeast China. The response of *Betula platyphylla* to precipitation and temperature was positively correlated with stem biomass and tree height but negatively correlated with the density. Which predict that forest ecosystem also needs a proper management practice for normal growth. As we know, forests are an important component of the global carbon cycle. *Betula platyphylla* forest management can contribute towards emissions reductions and to carbon sequestration. To increase *Betula platyphylla* forest capacity regarding biomass and carbon sequestration providing incentives for the maintenance of future and existing forest resource, enhancing regeneration to increase species composition and stocks, increase people participation in forest management, decelerating hot spot for carbon sequestration and protected area.

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