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RISE IN TEMPERATURE OF TWENTIETH CENTURY ENHANCED GROWTH OF *PINUS WALLICHIANA* TREES IN KARAKORAM REGION, NORTHERN PAKISTAN

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Abstract

The effect of global warming on trees growth have got great attention in last few decades. Most regions of the world reported the considerable growth changes in diverse forest types over the 20th century. Here, we explored the older trees of *Pinus wallichiana* from the Karakoram region, northern Pakistan. The results showed that the mean growth pattern in the high altitude in Karakoram region are strongly associated with warming pattern over the region. The tree growth enhanced due to high temperature in late 19th to 1st decade of the 21st century, while during the cold period of Little Ice Age (1500-1850 AD) the tree growth was suppressed. The log-suppressed growth of the trees still alive and give the important information about the tolerance of *Pinus wallichiana*. This indicates that increase of temperature was encouraging tree growth at upper treeline ecotone in the study area. However, if any effort in the future regarding tree growth-climate association is perceived, there should be the incorporation of more forest (tree-ring) sites along different altitudinal levels to acquire clear insights.

Key words: Tree rings, Climate change, Forest health, Temperature, Upper timber-line.

Introduction

Climate fundamentally controls a particular ecosystem functions, processing rate, and species range (Lenoir *et al.*, 2008). Recent warming (≥200 years) has significantly influenced the species dynamics and density of trees (Walther *et al.*, 2002). Research showed that temperature is the limiting climate factor for the growth of trees at upper treeline/ high altitude (Ko¨rner, 2003). Increasing in temperature strongly affect forest productivity and the competitive associations among tree species (Lindner *et al.*, 2010). Tree growth at high altitude are generally enhanced due to global warming (Harsch *et al.*, 2009). Tree growth responses to warming are crucial to assess forest productivity, future vegetation dynamics, plant diversity, and species richness (Büntgen *et al.*, 2007). Whereas, climate change can affect distribution, population structure, and growth of tree species (Devi *et al.*, 2008). Trees growth in mountainous ecotones was increased due to warmer temperature and decrease may possibly follow at some low-elevation sites (Albright *et al*., 2013).

Several dendroclimatological studies documented the evidences of tree responses to climatic warming (Schickhoff *et al.*, 2015; Brinkmann *et al.*, 2016; Ahmed *et al*., 2013; Asad *et al.*, 2016, 2017). Earlier studies investigated the history of temperature variation and its influence on forest structure and their growth worldwide described by Gonzalez *et al.*, (2010), Sasaki and Putz, (2009), and Xu *et al*., 2009). Tree-ring based forest growth estimated in china by He *et al.*, (2005) and Fan *et al.*, (2009). Whereas in Karakoram, a few studies have reported the impact of climate on tree growth, despite high dendroclimatological potential (Esper *et al.*, 2002; Ahmed *et al.*, 2011; Asad *et al.*, 2016), which is a great threat to decline the tree growth and their mortality (Liang *et al.*, 2015). Therefore, the growth of *Pinus wallichiana* species are essential to assess the significance of climate extreme during the past.

The objectives of this study is to examine the major growth variations of *Pinus wallichiana* during the past few centuries. To link those major growth variability with extreme events of the paleoclimate.

Materials and Methods

Pinus wallichiana is native and evergreen coniferous species over the Karakoram and Himalaya region of Pakistan. It is a dominated tree species in study area, where it is growing at elevation ranging from 3020 to 3504 m.a.s.l. The tree-ring samples were collected from upper treeline at two different localities i.e., Chaprot and Haramosh valley (Fig. 1). The increment cores were collected from healthy trees at breast height.

The climate data was obtained from nearest Gilgit weather station to sampling sites. The meteorological station located in the valley 1460 meters elevation. A climate record since 1955 A.D. of same station was received from of Pakistan Meteorological Department (PMD). Detail of tree rings cores and climate parameters are presented in (Table 1.) Monthly climate diagram of the Gilgit instrumental station for 1955-2013A.D showed high precipitation receives in spring (MAM) season, while monthly mean precipitation was 138.34mm. The trend of mean monthly temperature for the same period indicates that temperature gradually increases from January to July and then gradually falls up to December. The highest mean temperature noted for month of July 25°C, while the lowest mean temperature documented for January (15°C) (Fig. 2).

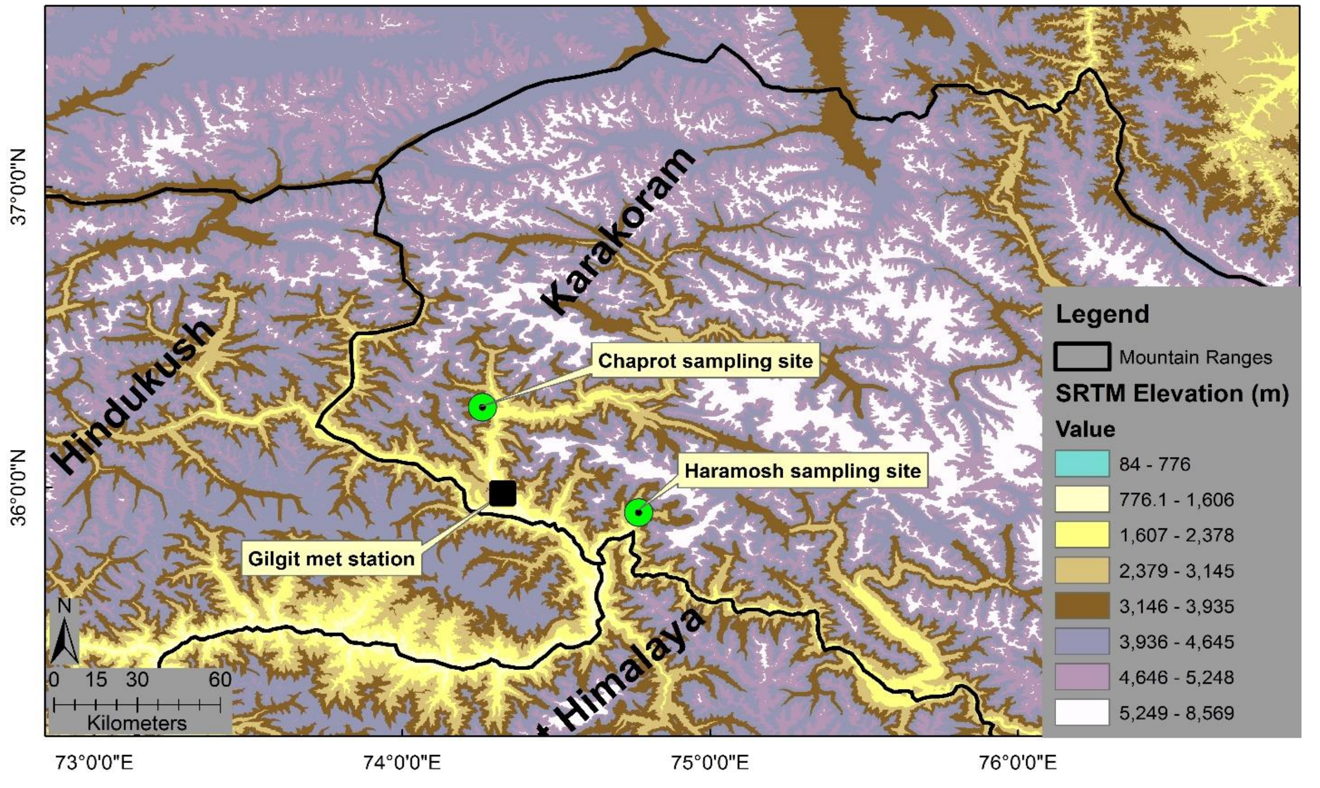

Fig. 1. Tree-ring sampling sites and Gilgit weather station of Karakoram region northern, Pakistan.

Table 1. Sites characteristics of two *Pinus wallichiana* forests.

Sampling site		Latitude (N)	Longitude (E)	Elevation (m)	Slope (º)	Forest Exposure
1.	Chaprot	36.26°	74.25°	3020-3404	33-38	South
2.	Haramosh	35.90°	74.93°	3130-3504	35-40	West

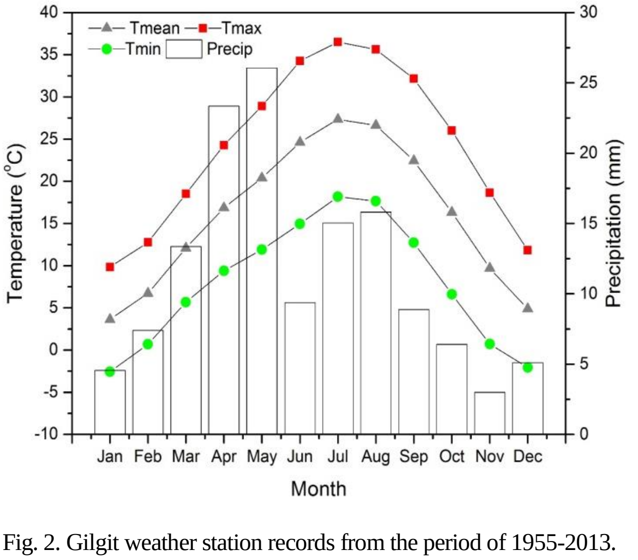

Fig. 2. Gilgit weather station records from the period of 1955-2013.

All samples were prepared in Laboratory by following standard dendrochronological methods (Stokes and Smiley, 1968; Fritts, 1976). Then tree rings width were measured up to 0.01mm accuracy using LINTAB 6 measuring system (Rinntech, Heidelberg, Germany). Tree rings series were cross-dated and then statistically confirmed by COFECHA software package (Holmes, 1983; Grissino-Mayer, 2001). Detrending and standardization were performed to remove age related growth trend (Cook, 1985) by using ARSTAN program and ratio between raw measurement and negative exponential function were also calculated (Cook & Kairiukstis, 1990).

The availability of the short instrumental climate records (1955 to 2013 A.D) are not enough to correlate it with tree-ring records that contain signals of major events related to growth variations during past centuries. Similarly, CRU climate data of grid points was also short (around one century), which do not clarify the objective of this study. Comparatively, reconstructed records of adjacent areas and northern hemispheric that already extracted from tree-rings. Therefore, the paleoclimate data sets were download from NOAA's National Centers for Environmental Information and applied the best matching climates with our finding.

Result and Discussion

Two raw tree-ring width (TRW) chronologies were developed using *Pinus wallichiana* trees from Chaprot and Haramosh (HRS) in Karakoram mountains of Pakistan (Fig. 2). The Chaprot (CPT) TRW record of 515 years (1500-2014 AD) from 35 trees (59 cores) and 495 years (1519-2013 AD) from 32 trees (63 cores) of the Haramosh valley. Both TRW (CPT and HRS) showed fluctuation around the mean (0.65 and 1.20), whereas the early growing period exhibit higher variability (Fig. 3).

TRW of CPT showed an increasing trend from early 19th century, while HRS showed from late 18th century. Comparatively, the reciprocal growth trend among the both TRW was observed from 1850 to 1900 AD, whereas the higher TRW increasing trend was observed for HRS (Fig 3a and b). However, to further check the trees growth trend, the mean chronology was developed for both sites, whereas the highest mean trees growth was recorded during the twentieth century of both site forest of study areas (Fig. 4). The lowest values of mean growth observed in ninetieth century, whereas the growth ratio in sixteenth and seventeenth centuries were fluctuated and relatively higher than mid-nineteenth century. The highest increasing tree growth trend observed in 1st decade of the 21st century, which revealed the highest among all previous centuries. The growth magnitude of both sites were different, whereas the trees growth of CPT was lower than HRS and insignificantly correlated with each other. Generally, trees produced narrow rings in harsh environment and in-contrast wide rings are formed when climatic conditions are favorable for their growth. This indicate that growth of individual trees may fluctuated with changing climate. Some plant species are flexible up to some degrees of climatic extremes below or above, those plants give adverse response (O'Sullivan *et al.*, 2016). Harsh climate for a long time, most of perennial plants become unhealthy and showed decline growth, whereas before death the radial growth of several tree species reached lowest rings width (Amoroso *et al.*, 2012). The results showed that climate change effect the tree growth may due to change of physiological activities such as photosynthesis, or transpiration. Because changes in water uptake and nutrients provision in growing meristems (Bond, 2000). Climatic variability acts as an environmental stress inciting and contributing to stand-level forest decline (Amoroso *et al*., 2015).

Northern hemispheric and regional paleoclimate climate data compared (Schneider *et al.*, 2015; Shi *et al*., 2013; Wilson *et al*., 2016; Asad *et al.*, 2016) to mean trees growth, to assess the past climate effect on forest growth. Trees growth of both sites were fluctuated during the 1500 to 1800 AD, which showed good agreement with past climate. The temperature around early nineteenth to mid nineteenth decreased, whereas the growth also decline in the study area. This decline and fluctuated growth of trees may due to cooling period, when the glaciers expanded throughout the world till to the end of Little Ice Age (LIA). Increasing temperature trend from mid-nineteenth to 1st decade of twenty 1st century are similar with mean growth trend of both sites. It showed that the majority of trees recovered the growth from decline to present time even with older age. Generally, it is understood warming in Humid/cold region enhanced the trees growth, due to the increasing length of growing season, which may also enhanced the rate of photosynthesis.

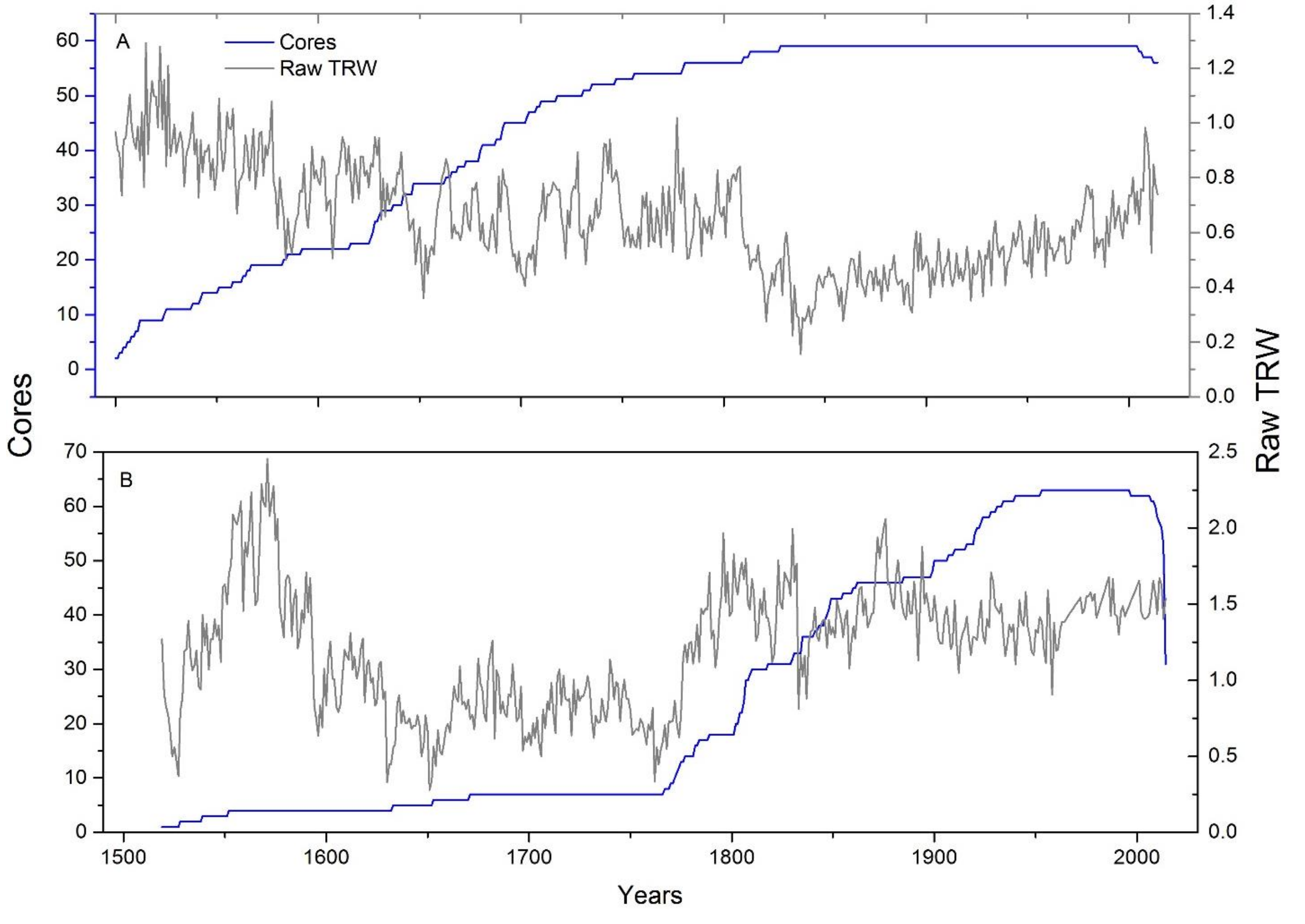

Fig. 3. Tree-ring chronologies of raw ring width of Chaprot (A) and Haramosh (B) region of northern Pakistan. The thick blue lines are the samples depths.

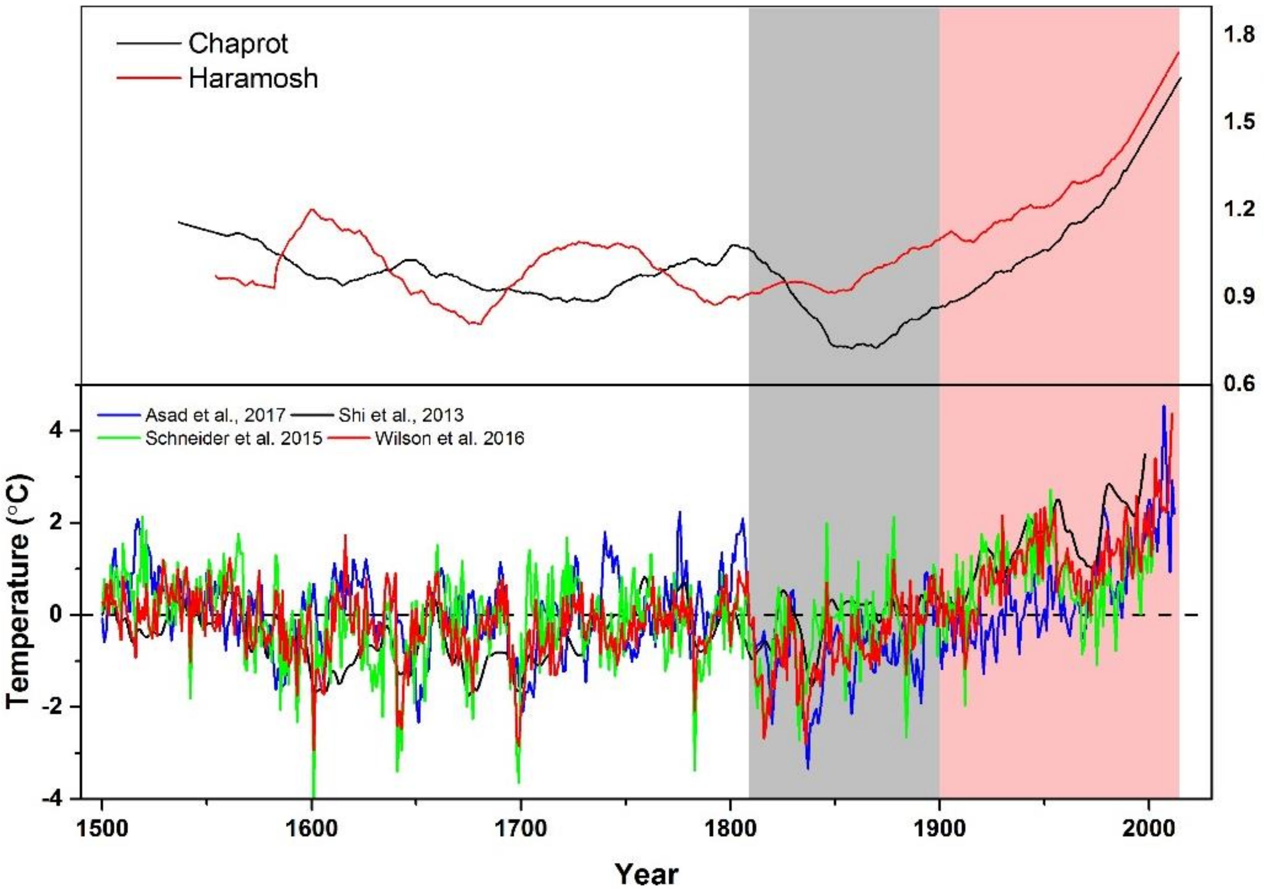

Fig. 4. Comparison of Chaprot and Harmosh chronology (Above panel) showed temperature reconstruction (below panel) of the selected area and Northern Hemisphere (Schneider *et al.,* 2015; Shi *et al.,* 2013; Wilson *et al.,* 2016; Fayaz *et al.,* 2016).

Conclusion

We analyzed the *Pinus wallichiana* growth of two forest of Karakoram region, northern Pakistan. The mean growth pattern in the high altitude trees observed during the past few century, which is strongly associated with increasing temperature pattern over the region. The results showed that the trees growth revealed similar response to temperatures. During the cooled period (LIA; AD 1500 to 1850) trees growth was decline, whereas the higher growth were observed after AD 1850-2015 may due to warming. This increasing growth trend after the long suppressed growth at upper treeline give the valuable information about the tolerance of the Karakoram Pine. The tree-growth during the 20th century was more frequent, indicated that high temperature was a key factor for tree/forest at upper treeline of the Karakoram region, northern Pakistan. However, if any effort in the future regarding tree growth and climate association is perceived, there should be the combination of several sites along different altitudinal levels to get clear insights.

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