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Climatic Warming due to Overgrazing on the Tibetan Plateau

- An Example at Damxung in the Central Part of the Tibetan Plateau -

Mingyuan DU*[1], Seiichiro YONEMURA[1], Xianzhou ZHANG[2], Yongtao HE[2], Jingshi LIU[3] and Shigeto KAWASHIMA[4]

Abstract: Many studies have shown that the increase in air temperature on the Tibetan Plateau is greater than that for the Northern Hemisphere and the same latitudinal zone. Recent paper has pointed that this warming; especially warming in wintertime is clearer at lower altitude than at higher altitude on the Tibetan Plateau and the local environmental changes such as urbanization and land cover change may play very important role for the geographical changes of recent climate warming. However, there is no any concrete evidence to support this hypothesis. This paper identifies the relationship between overgrazing and climate warming at Damxung in the central part of the Tibetan Plateau by using recent 47 years data of Damxung meteorological observatory station and 5 years intensive observations data on a pasture on a mountain slope where overgrazing is occurred in the lower part of the slope. Meteorological data reconstruction of the pasture is carried out by using the relationships between the observation data on a pasture and the meteorological observatory's data. Annual air temperature both at the meteorological observatory and at the overgrazed pasture has increased about 2 degrees during past 47 years and this extreme air temperature increasing at Damxung is mainly caused by the degradation of grassland due to overgrazing. It provides evidence that degradation of grassland due to overgrazing promote the climate warming and thereby the land and vegetation degradation process.

Key Words: Climatic warming, Data reconstruction, Land degradation, Overgrazing, Tibetan Plateau.

1. Introduction

It is well known that the thermal and dynamical processes of Tibetan Plateau (TP) have a profound influence both to climate and to ecosystems of the Asian continent and even the whole world. Research on the climate and cryospheric change in the TP has received increasing attention since mid-1970s as Kang *et al*. (2010) reviewed. Many works showed that the main portion of the TP has experienced statistically significant warming since the mid-1950s, especially in winter, which exceed that of its surrounding regions (e.g. Liu and Chen, 2000, Du *et al*., 2004, Lu and Liu, 2010). Most of the works assumed this is the global warming effects. However, Frauenfeld *et al*. (2005) pointed out that "The significant trends in station data may reflect the extensive land use change and industrialization that has occurred on the Tibetan Plateau" because no trends are observed in ERA-40 reanalysis data. Du *et al*. (2004, 2010) pointed that degradation of grassland on the TP should have been affected the climate change on the TP and may be one of the reasons why climate warming on the TP is greater than on other places and why recent warming is clearer at lower altitude than at higher altitude on the TP. However, there is no any confidential evidence to support this hypothesis due to lack of data. This paper is an attempt to clarify the relationship between overgrazing and climate warming at Damxung in the central part of the TP by using recent 47 years data of Damxung meteorological observatory station and 5 years intensive observations data on the mountain slope pasture, where overgrazing is occurred in the lower part of the slope.

2. Data and Methods

2.1. Observation site description

In order to clarify the local climate features, we have selected a pasture on a south facing slope in the central part of the TP. **Figure 1** shows the main topography over the TP and the observation sites. Damxung meteorological observatory station is located near the small town Damxung in the valley (about 4280m a.s.l.). The low and middle part of the mountain slope (between 4300 m and 5200 m a.s.l.) is used as pastures, where overgrazing is occurred in the lower part (4300 m to 4600 m) of the slope (Ohtsuka *et al*., 2008). We set up 11 observation stations on a south slope of Mount Nyainqentanglha as shown in Figure 1 (down) at Damxung (30º28-32'N, 91º02-03'E) in 2005. One of the 11 stations is a basic automatic station at about 4300 m in the valley. All the

* Corresponding Author: dumy@affrc.go.jp
3-1-3 Kannondai, Tsukuba, Ibaraki, 305-8604 Japan
1) Department of Agro-Meteorology, National Institute for Agro-Environmental Sciences, Japan
2) Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, China
3) Institute of Tibetan Plateau, Chinese Academy of Sciences, China
4) Kyoto University, Japan

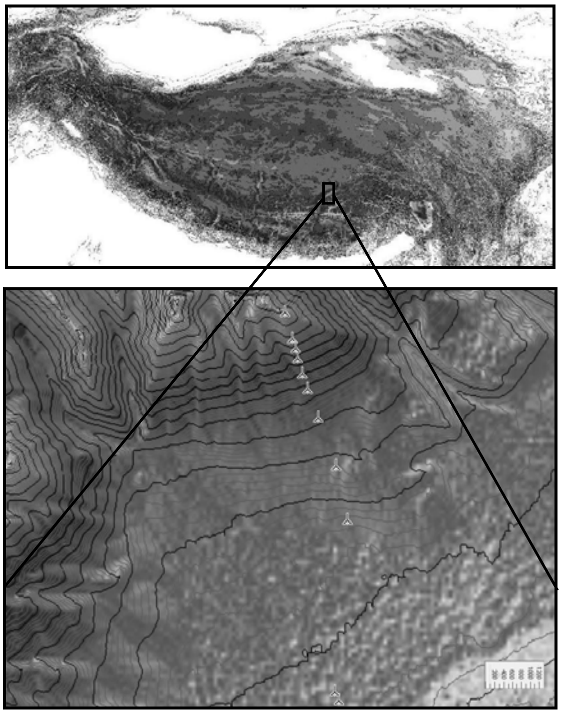

Fig. 1. The main topography over the Tibetan Plateau (up) and observation stations (down). The Tibetan Plateau is shown as the shaded region where elevation is higher than 3000 m a.s.l.. Black contour lines show topography with an interval of 1000 m (up) and 100 m (down). The triangles indicate the observation stations.

meteorological elements including short and long wave radiations, wind speed and direction, air temperature and humidity, soil temperature and water content etc. were measured there by using measurement system of Campbell Scientific, Inc. Data were recorded with a data-logger (CR10X; CSI) at 30 min intervals. Measurement system on the other 10 stations are Hobo weather stations (Onset Computer Corporation, Bourne, MA, USA) settled at 4300 m, 4400 m, 4500 m, 4650 m, 4800 m, 4950 m, 5100 m, 5200 m, 5300 m and 5530 m on a south slope. Stations at 4300 m are located on a wet land. Stations at 5300 m and 5530 m are located on a bare land and others are located in the pasture. Air temperature and humidity at 2 m and soil temperature and soil water content at 5 cm, 20 cm and 50 cm are sampled at 1 min intervals and the mean value were recorded with a data-logger at 30 min intervals. The air temperature data from August, 2005 to July, 2010 are used in this study.

2.2. Data and method

Daily mean of air temperature (T), minimum and maximum air temperature (Tmin and Tmax), air pressure (P), absolute and relative humidity (e and RH), low and total cloud amount (Cl and C), wind speed (V), surface temperature (Ts), precipitation (Rain), sunshine hour (S) and pan evaporation (Et) of the Damxung meteorological observatory station from

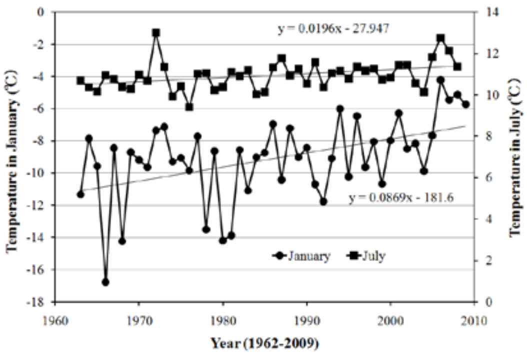

Fig. 2. Observed Air temperature variation during 1962 to 2010 at Damxung.

August 1, 1962 to June 30, 2009 are used.

Stepwise linear regression method was used for getting relationship between daily mean air temperature on the slope and the meteorological elements of the Damxung meteorological observatory station by using SAS software (SAS institute inc., Cary, NC, USA) with *t*-test at statistical significance determined at the $P < 0.05$ level. Due that the mechanism of local temperature varies for different seasons, we get the relationships for each month. Therefore,

$$Tcal_{ij} = a_{ij} + \sum_{k=1}^{k=m} b_{ijk} E_k \qquad (1)$$

where, $Tcal_{ij}$ is estimated air temperature for station i month j (i=1, 10; j=1, 12) . a_{ij} and b_{ijk} are regression coefficients of station i month j for meteorological elements E_k (E_k=T, Tmax, Tmin, P, e, RH, Cl, C, V, Ts, Rain, S, Et).

We assume that the relationship between daily mean air temperature on the slope and the meteorological elements of the Damxung meteorological observatory should reflect the effects of land degradation by overgrazing and may be the same in the past 47 years. Therefore, we can use the relationship to reconstruct the daily mean air temperature during 1962 to 2004 on the slope and then to calculate the 18 years mean temperature for 1962-1980 due to there was almost no temperature increase during this period as shown in **Figure 2**. Therefore, we can compare the temperature differences between the observed mean of 2005 to 2010 and the estimated mean of 1962-1980.

3. Results and Discussion

3.1. Climate warming at Damxung

As shown in Figure 2, observed air temperature at Damxung meteorological observatory shows statistically significant increase trend for each month, especially in winter time (0.02°C /year in July and 0.087°C /year in January). Increase in daily minimum air temperature is clearer (0.022°C /year in July and 0.114°C /year in January). Annual air

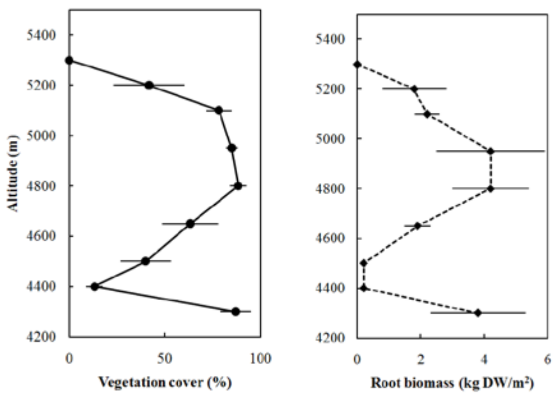

Fig. 3. Vertical distribution of vegetation coverage and root biomass along the south slope (redraw from Ohtsuka *et al*., 2008 and data at 4300m is with personal communication)

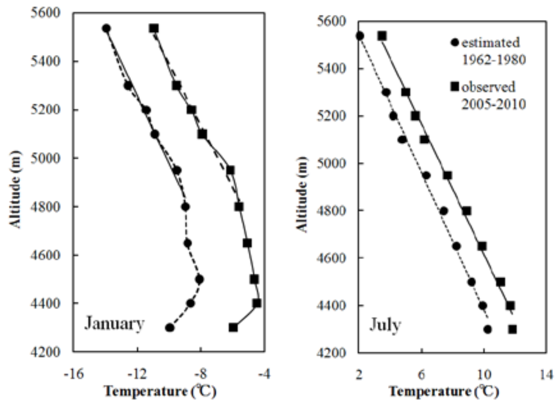

Fig. 4. Observed and estimated air temperature variation along the slope during 2005 to 2010 and 1962 to 1980.

temperature at the meteorological observatory has increased about 2 degrees during past 47 years. This increase in air temperature is higher than other places on the TP at similar altitudes and surrounding area.

3.2. Overgrazing and vegetation cover change

Figure 3 shows the distribution of vegetation coverage and and relation between root biomass and elevation along the south slope in 2005. It can be seen that both vegetation coverage and root biomass at the lower part of the slope (between 4400-4650 m a.s.l.) was smaller than that at the middle part of the slope and that in the valley (4300 m). This is due to the overgrazing there. The middle part of the slope has been used as summer pasture and the valley wet land has been used as winter pasture, while the lower part of the slope is been used throughout a year because most of herdsmen are living at the lower part of the slope. Interviews with the herdsmen let us know that this overgrazing was occurred around 1980 and becoming more and more remarkable with the increase in livestock numbers as shown by Du *et al*. (2004).

3.3. Air temperature distribution along the slope and its changes

As shown in **Figure 4**, observation data (mean of 2005 to 2010) along the slope shows a uniform lapse rate about 0.72 ºC/100m along the slope, in summer season. This lapse rate is greater than that of averaged over the TP (Du *et al*., 2010). However, there is an inversion layer at lower part of slope (below 4800m) and a relatively larger lapse rate about 0.79 ºC/100m at higher part of the slope in wintertime. This is due to strong radiation cooling based on lower humidity and cold air run-off from a higher mountain region into the valley by a local circulation, the air temperature in the valley becomes lower and lower during night in wintertime. This process occurred and a temperature inversion layer exited almost occurred everyday during wintertime as Du *et al*. (2009) described. However, air temperature at the lower part of the slope is little bit higher than the lapse rate predicted (right up the lapse line shown in Figure 4) in summertime and higher in winter partly due to the temperature inversion.

Figure 4 also shows the estimated mean temperature (1962 -1980) distribution along the slope. It shows a similar distribution pattern as observed one (mean of 2005 to 2010) with significant increase of air temperature throughout the slope, especially in January. However, there is evidently high value of the temperature in the overgrazed lower part of the slope. Therefore, the lapse rate in summer changes from 0.72ºC/100m to 0.69ºC/100 m. Although this value is still larger than that of averaged over the TP, this value can be treated as a natural environmental, which do not induced land degradation. Lapse rate at higher part of the slope changes from 0.79ºC/100m to 0.72ºC/100m in wintertime.

3.4. Relationship between overgrazing and climate warming at Damxung

Land degradation by overgrazing can affect climate change (e.g. Jackson and Idso, 1975; Balling, 1998; Du, 1996). Many researchers have found that decrease in vegetation cover reduces evapotranspiration thereby allowing an increase in local temperature levels. Balling (1998) has revealed that overgrazing and consequently land degradation in semiarid areas of northern Mexico resulted in significantly air temperatures increase both in northern Mexico and in its adjacent Arizona, USA. Damxung meteorological observatory is located very near to the overgrazing pasture. Therefore, air temperature increase has coincided with the progress of overgrazing since 1980 as shown in Figure 2.

Moreover, the land degradation effect were reflected upon not only the air temperature but also all the observed meteorological elements at Damxung meteorological observatory. For example, humidity (e and RH) and cloud amount (C and Cl) have decreased and sunshine hour (S) has

Table 1. Comparison of regression coefficients of station 4400 m and 5300 m.

Station & month	a_{ij}	b_{ij} P	T	Tmax	Tmin	e	RH
4400m Jan.	-1.798		0.829	0.342			
5300m Jan.	-13.593		0.341	0.804			0.036
4400m Jul.	-58.451	0.094	0.768	0.196			
5300m Jul.	-182.873	0.287	0.833	0.187	-0.337		

(Continue of Table 1.)

Station & month	b_{ij} C	Cl	V	Ts	Rain	S	Et
4400m Jan.				-0.182			
5300m Jan.				-0.266		-0.086	
4400m Jul.					-0.018		
5300m Jul.	0.015				-0.027		

increased slightly. Air temperature at the pasture and surrounding area has been also affected by the land degradation. These variations have effects on air temperature at different area of the slope pasture with the relationship obtained by the stepwise linear regression. **Table 1** shows the comparison of regression coefficients for July and January of station 4400 m and station 5300 m. As shown in Table 1, despite the regression coefficients differences, there are two more elements (RH and S in January, Tmin and C in July) selected for station 5300 m. Since RH and C are decreased and Tmin and S is increased and air temperature at 5300 m is directly proportional to RH and C and inversely proportional to S and Tmin, this is one of the reasons of increase amount of air temperature at 5300 m is smaller than that at 4400 m.

4. Conclusion (or Recommendation)

Both observed air temperature at the meteorological observatory and estimated air temperature at the overgrazed pasture at Damxung has increased about 2 degrees during past 47 years and this extreme air temperature increase is mainly caused by the land degradation due to overgrazing by following reasons.

(1) 47 years observed air temperature at the meteorological observatory has increased since 1980 which coincides with the progress of the overgrazing.

(2) 5 year observed air temperature at the pasture shows relative higher value at the overgrazed area.

(3) Estimated air temperature at the pasture shows more increase amount at the overgrazed area than other area.

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