REMOTE SENSING AND GIS APPROACH FOR CAPTURING HERDERS' INDIGENOUS KNOWLEDGE OF SELECTING SUITABLE AREAS FOR WINTER CAMP LOCATIONS IN MONGOLIA

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ABSTRACT: The extreme cold winter disaster 2009/2010 resulted in a significant loss of livestock in many parts of Mongolia. Although much knowledge of selecting suitable areas for winter camping has been orally passed down in the Mongolian nomadic life for thousands of years, some of such undocumented knowledge seems to have got lost during the recent changes in the society particularly after Mongolia's transition to a market economy in 1990. The apparent inversion layer—where an increase in temperature with height occurs—was evident at night time during January 2010. The author depicted the spatial extent of the inversion layer using the MODIS land surface temperature (LST) standard product and compared its distribution with topography. Among all 275 winter camps recorded in Bayandelger district (47° 44' N, 108° 08' E, 2,800km^2) located in 90km east of the nation's capital Ulaanbaatar, 205 (75%) camps were found in the elevation between 1500m and 2000m above mean sea level (300-800m above the plain). LST below and above were lower than those in this elevation range. Identification and visualization of inversion layer and its spatial extent with other key components like the amount of available forage incorporated in a GIS can help the new herders and local government to make sound decisions.

INTRODUCTION

Mongolia, located between Russia and China, is the second largest landlocked country in the world. The country has a total area of over 1.56 million km^2 and lies on the high Mongolian plateau that ranges from 900 to 1500m in elevation. The Mongolian territory is characterized by rocky deserts and grassy semi-arid temperate steppes. It has an extreme continental climate with long, cold winters and short summers. Annual rainfall seldom exceeds 400mm in the northern mountains and 100mm in the southern areas.

Pastoral nomadism has been the dominant economic force in Mongolia for many thousands of years. Pastoralism in Mongolia depends on the exploitation of the extensive but seasonal steppe and mountain pastures. Since most of the country is hot in short summer but extremely cold in long winter with January average dropping as low as -30°C, posing risks to subsistence of livestock, selection of suitable areas for putting winter camps is critically important for herders. Winter camps are commonly equipped with shelters, in the form of huts.

It is a common understanding that there are some undocumented rules that have been passed down from generation to generation for selecting the appropriate winter camp locations. Such favored locations are often considered to include lower-lying mountain valleys, the banks of streambeds, and shallow depressions on the steppe (Barfield, 2011). A windswept area free of snow is also considered preferable. However, these rules, often taken it for granted, haven't got formalized and thus can be vulnerable to get lost.

A significant number of livestock was lost in many parts of Mongolia during the extreme cold winter disaster, locally called Dzud, in winter 2009/2010. It's been speculated that the sheer magnitude of economic loss may have been partially attributable to the insufficient preparation for the harsh winter conditions by some herders. When Mongolia made a transition to a market economy in 1990, many former cooperative farmers under the Soviet system went back to herding but may have missed some Mongolian-specific indigenous knowledge about livestock husbandry.

Preliminary micrometeorological observation in Bulgan province (48° 50' N, 103° 20' E) in 2009/2010 indicated that night time temperature at a well-planned herder's winter camp location was higher than that in summer time pasture areas by up to 20°C despite the fact that winter camp was located as much as 200m higher in elevation (Hirano *et al*. 2012). This suggested a comparative advantage of putting a camp in higher elevation in winter time.

However, the ground observation was limited by point-based automated weather station (AWS) recording and fell short in portraying the spatial context in geographic domain. As Kondoh et al. (1997) demonstrated, the satellite-based thermal imagery can be used to show the extensive temperature distribution.

The objective of this study is to attempt to capture and formalize the undocumented rule in selecting suitable areas for winter camp sites in Mongolia using remote sensing technology.

STUDY AREA

Bayandelger district (47° 44' N, 108° 08' E, 2,800km^2) is located about 90km east of the nation's capital Ulaanbaatar and belongs to the forest steppe zone, one of six natural ecological zones in Mongolia. The elevation ranges from around 1200m above sea level in the high plains to over 2200m at several mountain peaks. All winter camp locations with shelters were recorded on the ground using a GPS. There were 275 winter camps in total in the district.

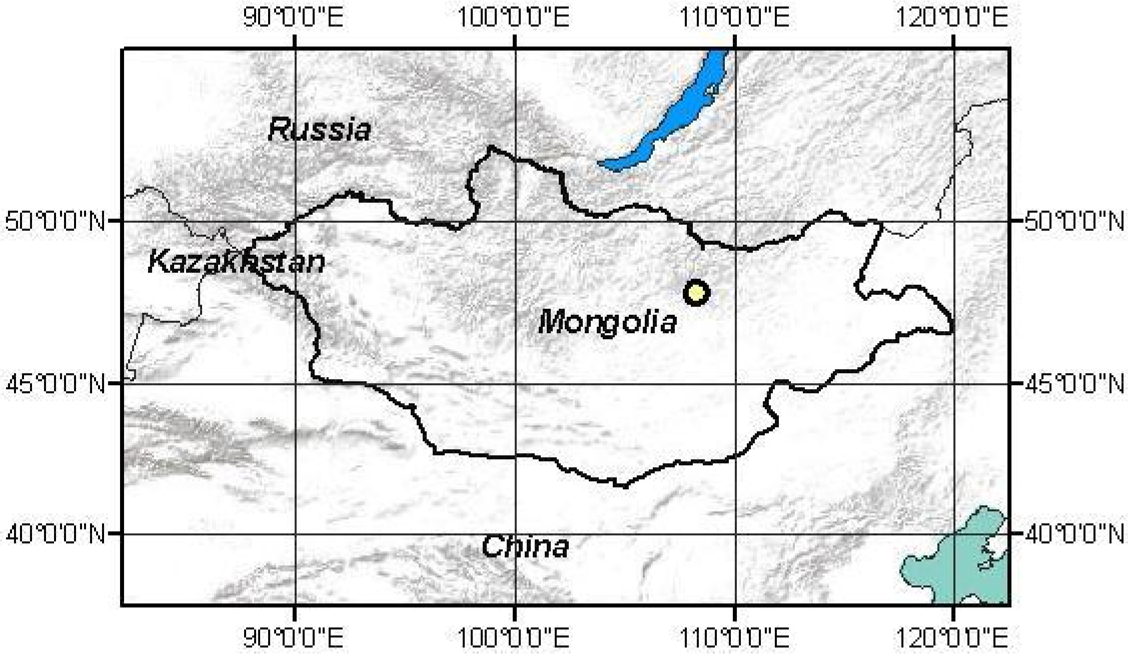

Figure 1: Location of the study area.

DATA AND METHODOLOGY

I used the MODIS standard data product MOD11A2 (Land surface temperature & emissivity 8-day L3 Global 1km, Ver.5) to depict the district-wide distribution of land surface temperature (LST). Table 1 shows the list of MODIS LST data sets used in this study for winter (in the midst of severe Dzud) and summer (at the time of phenological maximum in the region) in 2010.

Table 1: List of MODIS LST data sets used in this study.

Season	Data set	Satellite	Sensor	Begin date	End date
Winter	MOD11A2.5	Terra	MODIS	2012-01-10	2010-01-16
Summer	MOD11A2.5	Terra	MODIS	2012-08-08	2010-08-14

MODIS LST data are originally recorded in Kelvin so the values needed to be scaled and converted to degree Celsius. In addition to the winter time LST, summer time LST was processed for comparison. Each data set contained both day-time and night-time LST. Only the night-time LST was used to evaluate the decisive conditions for livestock survival in winter.

For the topographic representation, I used the Shuttle Radar Topography Mission (SRTM) Ver.4 data set of the study area. This global digital elevation model (DEM) has a resolution of 90m and agreed well with spot heights in the local topographic maps.

The night-time LST were overlaid on top of the topography in a geographic information systems (GIS) for visual interpretation. In order to examine the temperature-elevation relationship, 3000 random points were generated across the 60 × 120km area and were displayed on a scatter plot. All winter camps' temperature and elevation were added to the same scatter plot to see their distribution.

RESULTS AND DISCUSSION

Figure 2a and 2b show the night-time LST distribution of winter and summer 2010 superimposed on top the topography. Red color denotes warm temperature while blue denotes cold temperature. Dots in the graphics represent the location of winter camps in Bayandelger district. In summer, the normal vertical temperature gradient is apparent: the temperature decreases with increasing elevation on the slopes (Figure 2a). However in winter, temperature on the low-lying plains is colder than that on the slopes (Figure 2b).

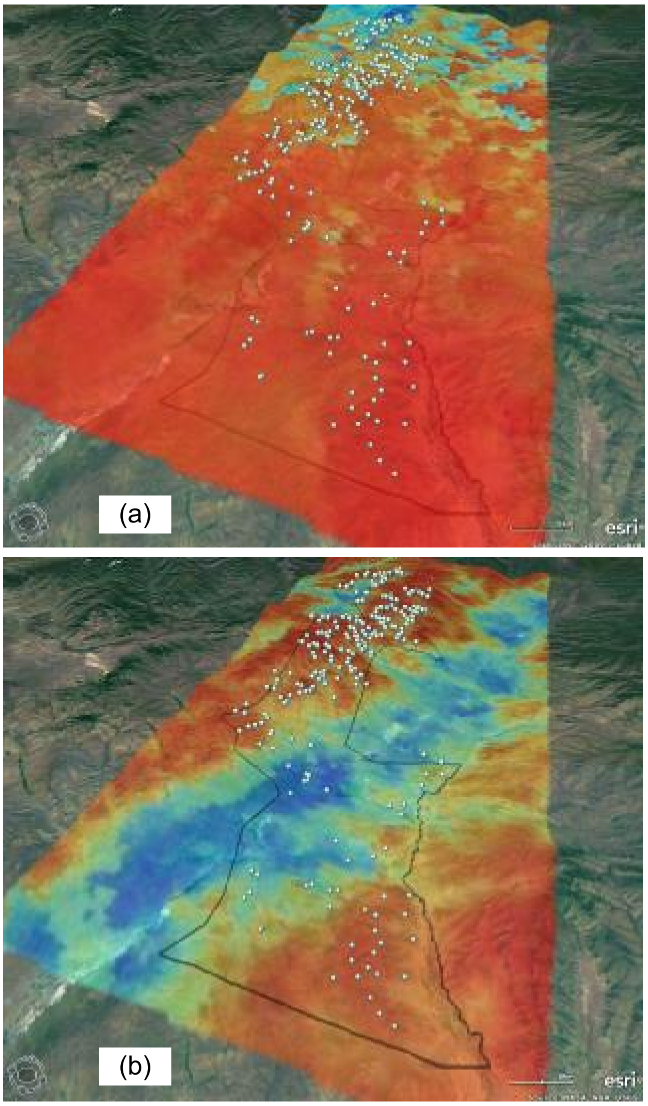

Figure 2: Night-time LST superimposed on top of the topography; a) summer, b) winter.

The distribution of randomly generated 3000 samples across the 60 × 120km in the vicinity of Bayandelger district is shown in Figure 3. SRTM DEM and the night-time LST of winter 2010 are being displayed beneath the sample locations for reference.

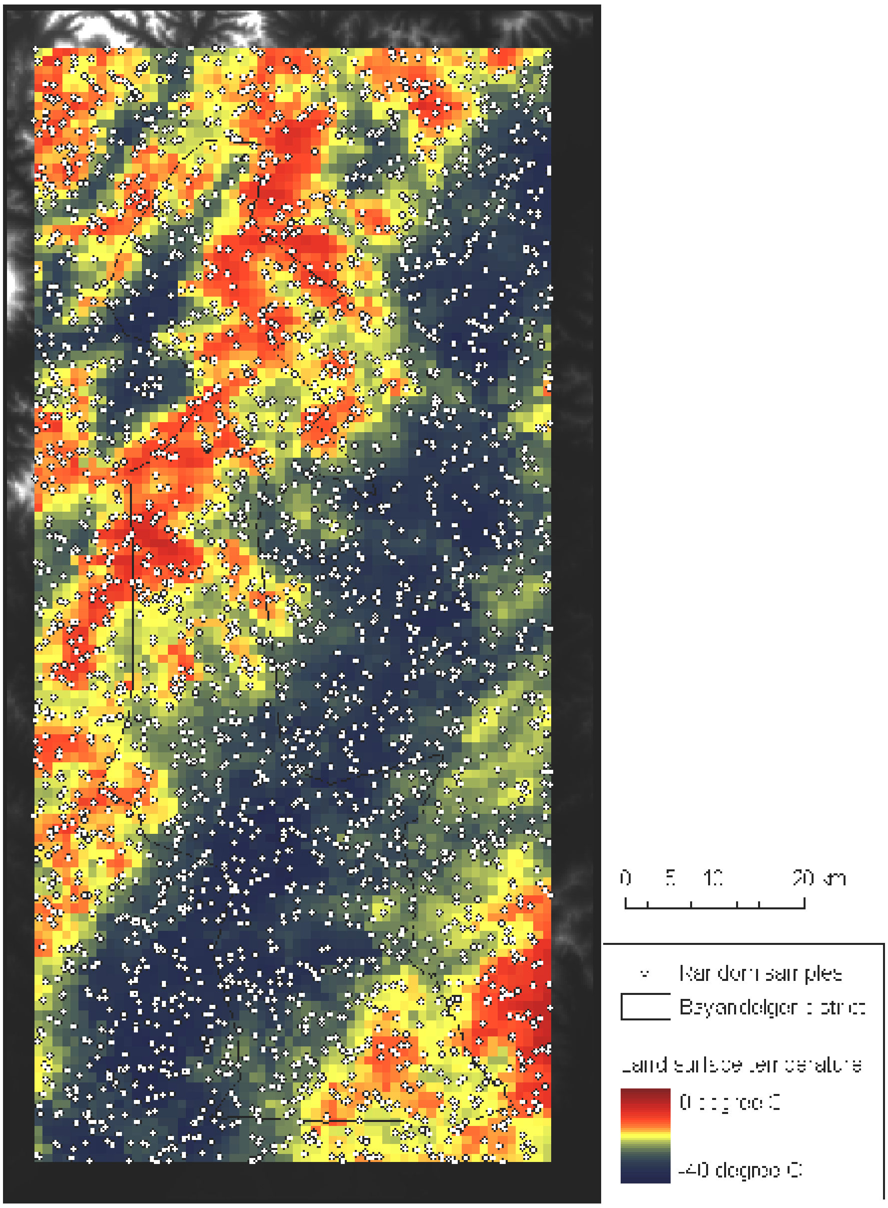

Figure 3: Locations of 3000 randomly distributed samples for retrieving pairs of LST and elevations. Displayed underneath is the distribution of the night-time LST in winter 2010.

Figure 4 shows the scatter plot of LST and elevations of the 3000 random samples. Contrary to the normal vertical temperature gradient, temperature keeps decreasing as elevation gets higher until about 2200m above means sea level or 1000m above the low-lying plains: presence of an inversion layer. A thermal belt, a zone of high night-time temperatures that is often experienced within a narrow altitude range on valley sidewalls, can be identified roughly between 1400m and 2100m.

Night-time LST and elevations for all 275 winter camps in Bayandelger district were retrieved and added to the scatter plot in Figure 5. A 75% (205 winter camps) fell in the elevation range identified as the thermal belt.

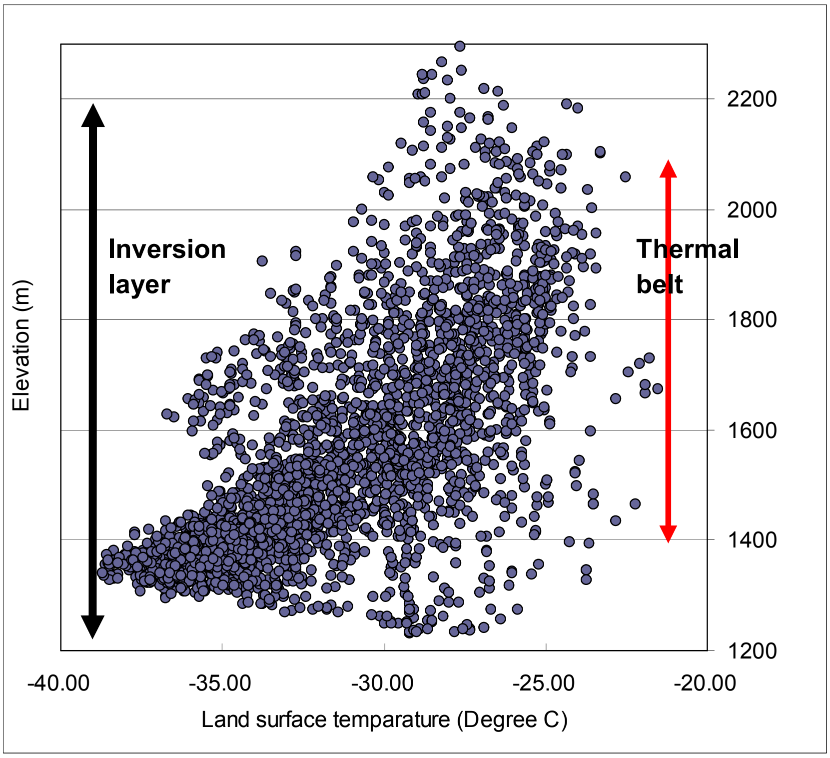

Figure 4: Scatter plot of night-time LST vs. elevations for 3000 randomly distributed samples across Bayandelger district and the vicinity in winter 2010.

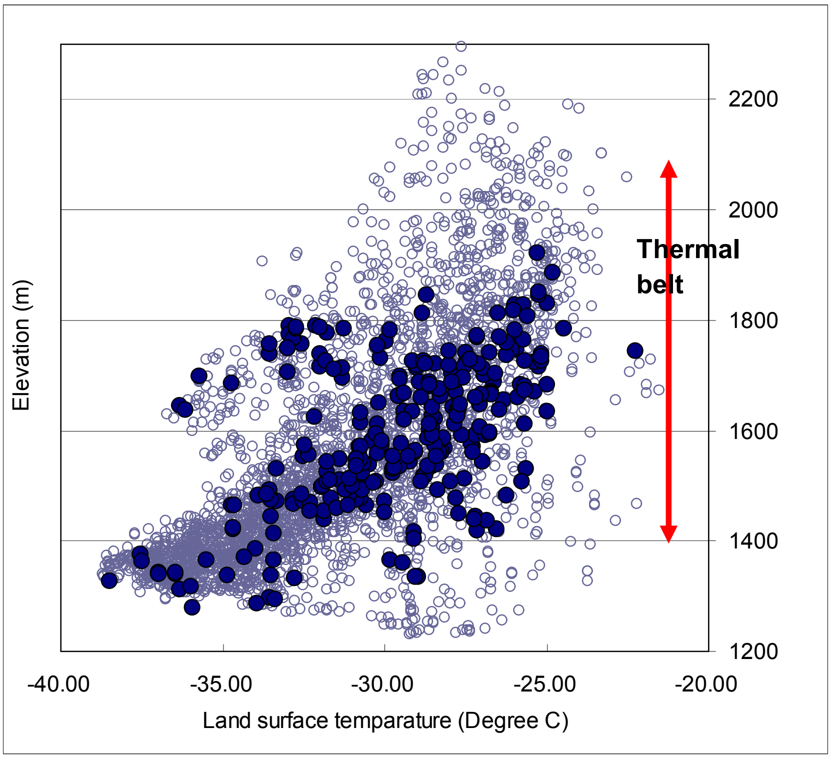

Figure 5: Night-time LST and elevations for all winter camps in Bayandelger district in winter 2010 are added to the scatter plot (shown with dark blue dots).

The fact that 75% of all winter camps/shelters in the district were found on the slopes in the thermal belt suggests that this indeed is a preferred area for placing winter shelters. Some winter camps are located below the thermal belt where temperature becomes extremely low, but these camps tended to be placed near or along the major road network making it easier for herders to maneuver around the winter disaster. No winter camp was found above the thermal belt where temperature starts decreasing again with altitude and the slopes are too steep.

Although the selection of favored locations for putting winter camps additionally requires more factors like wind speed, wind direction, topographic aspect, proximity to water sources, the amount of available forage, etc., it is assumed that simple boundary determination based on night-time temperature can provide an essential criterion.

CONCLUSIONS

The use of thermal satellite sensing helped to expand the knowledge gained from the micrometeorological observation to a much larger geographical extent. During the severe winter 2010 in Mongolia, an apparent inversion layer and thermal belt were identified. Results showed that most winter camps in the study area were located in the thermal belt indicating that herders traditionally selected these locations based on the favorable thermal conditions in harsh winter.

Herders' indigenous knowledge about sustainable livestock husbandry comprises variety of undocumented sets of knowledge. The spatial identification of thermal belt using the information gathered from remotely sensed image data can provide an essential layer representing a criterion for selecting suitable areas for winter camp locations. The empirical approach demonstrated in this study has a potential for gaining a new perspective on capturing and formalizing the indigenous knowledge about livestock husbandry in Mongolia. The captured knowledge can be used by the new herders and local government to make sound decisions even when tradition gets lost.

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