Climate change impact on rangeland productivity in Mongolia

Dennis Ojima[1] , Jeff Hicke[1], Xiao Xiangming,
Sayat Temirbekov, Togtohyn Chuluun[1,2]

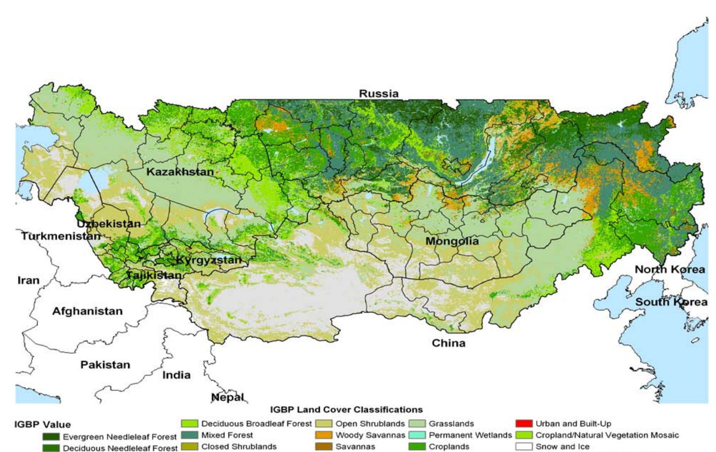
1 - Natural Resource Ecology Laboratory, Colorado State University, Fort Collins, Colorado 80523-1499, U.S.A., dennis@nrel.colostate.edu
2-Department of Meteorology, Hydrology and Ecology, National University of Mongolia, Ulaanbaatar, Mongolia
3 - Institute of Meteorology and Hydrology, Khudaldaany gudamj – 11, Ulaanbaatar – 46, Mongolia

Abstract

Dramatic changes occurred in pastoral systems of Mongolia, China and in Central Asia, including portions of Russia for past decades (Figure 1). Integrated assessment of these changes on environment and quality of life is essential for sustainability of the region. Land use changes due social-political events and climate change have influenced land management strategies affecting the C cycle, environment, and human systems. Recently, evaluation of the pastoral systems has been conducted in the region. These pastoral systems, where humans depend on livestock, exist largely in arid or semi-arid ecosystems where climate is highly variable. Thus, in many ways pastoral systems are adapted to climatic variability. Remote sensing and modeling of this inter-annual variability is critical to understanding the C fluxes, ecosystem dynamics and nomadic land use systems in the region.

We also recognize the pervasive role of demographic, political and economic driving forces on land resource use and carbon emissions in the region. This region provides an unique research opportunity to evaluate the role societal dynamics have affected large scale biogeochemical dynamics as reflected in C sources and sinks in the region. The early trend in the last century was toward greater intensification of resource exploitation at the expense of traditional patterns of extensive range utilization, and in recent times with the collapse of the central government systems in the region has resulted in different strategies of land use intensity. This set of drivers is orthogonal to the above described climate drivers. Thus we expect climate-land use-land cover relationships to be crucially modified by the socio-economic forces mentioned above. Nevertheless, the complex relationship between climate variability and pastoral exploitation patterns will still form the environmental framework for overall patterns of land use change and C dynamics.

Figure 1. Geographic domain of study region.



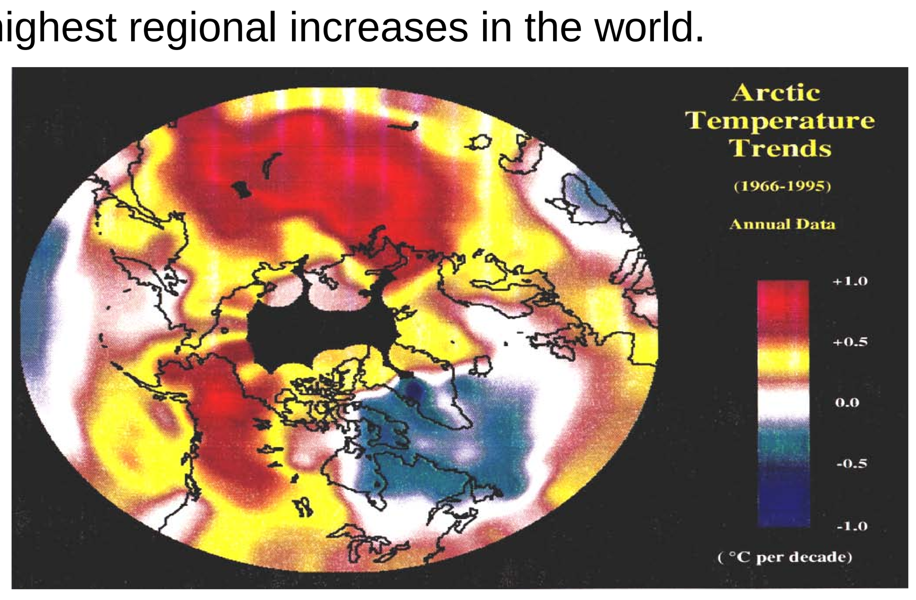
Introduction

In the semiarid regions of the Eurasian steppe, nomadic pastoralism and dryland agriculture have been the dominant agronomic activity for many centuries. Recent changes in cultural, political and economic factors have caused changes in the intensification of land use operations within the region and recent climate changes (Figure 2) seem to be affecting C fluxes from the region (Figure 3).

Pastoral systems, where humans depend on livestock, exist largely in arid or semi-arid ecosystems where climate is highly variable. Thus, in many ways, the historical pastoral livestock systems are intimately adapted to climatic variability. Climate change in drylands can thus be expected to have important implications for the ecosystem dynamics and exploitation patterns of land resources, including carbon dynamics.

During the past decade, land use intensity has been sharply modified due to changes in the socio-political conditions in the region and the role related to the collapse of the central government, forced entry into the open market system, reduction of government support systems, and collective land use systems. The response to the changes vary across the region and are somewhat reflected in the national level socio-cultural-economic condition. ***Our project aims to disentangle the physical and the human dimensions of land use patterns in the region to understand the factors affecting land-based sources and sinks of C-dynamics.***

Figure 2. Climate trends over Northern Eurasian indicate the highest regional increases in the world.



Climate Trends (Figure 2)

In the last 60 years, the mean annual air temperature increased by 1.56 C, due to winter warming (Mongolia National Action Program on Climate Change 2000). Changes in warming are more pronounced in the high mountains and mountain valley, and less in the Gobi desert and the steppe. There is a slight increase in the annual precipitation in the last 60 years (Natsagdorj 2000). The frequency of extreme events such as drought, flood, dust storm, thunderstorm, heavy snow, and flash flooding, has increased over the past 30 years (Natsagdorj 2000).

It is likely that the boundary zone between the Gobi desert and steppe is already affected by global warming and land use impact. Analysis of onset of green-up (Figure 4), an indicator of spring thaw and the initiation of the growing season, during the 1982 to 1991 time period indicates that large portions of eastern Mongolia and Inner Mongolia are experiencing earlier green-up. This region of advanced green-up is dominated by Meadow Steppe and relatively mesic areas of typical steppe. There are also large portions of the desert steppe and dry areas of the typical steppe, where there is a strong trend towards delayed green-up.

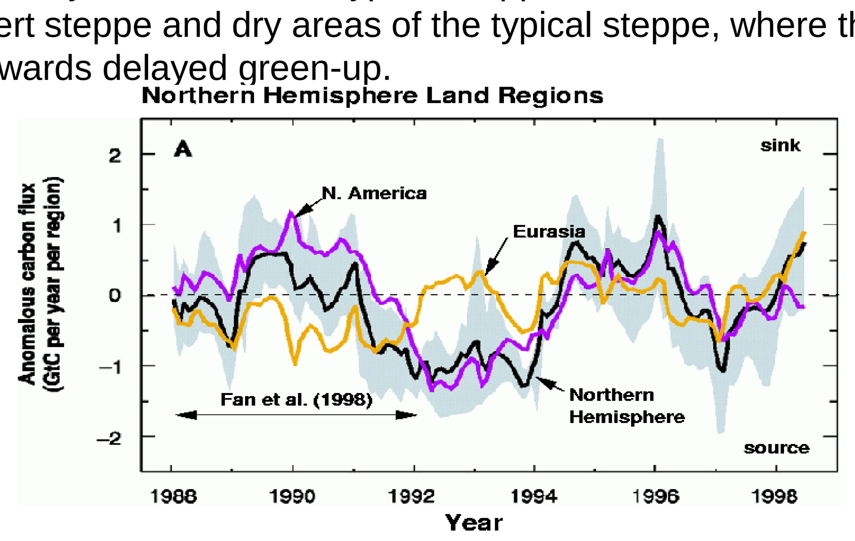
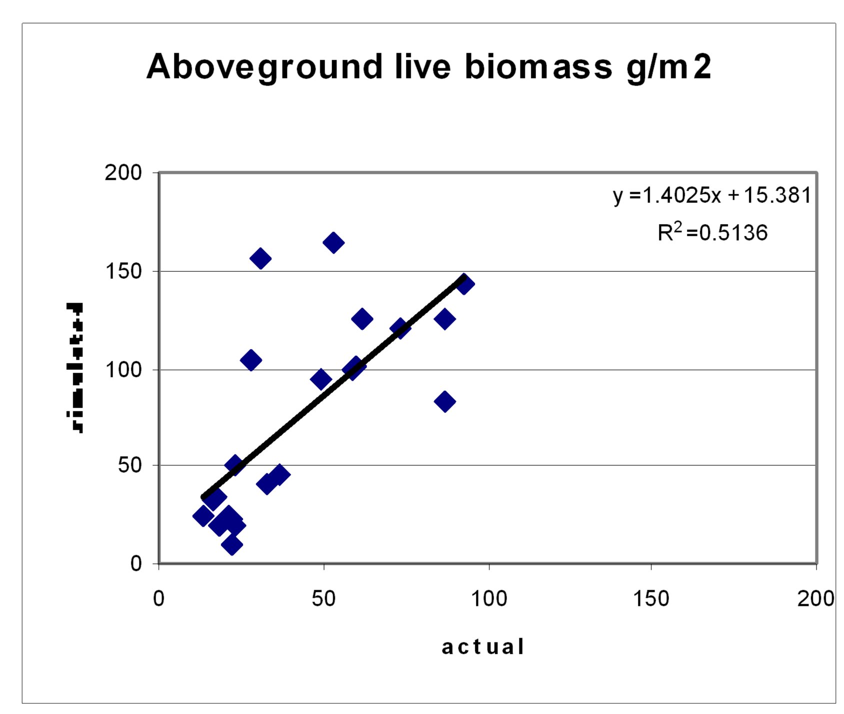


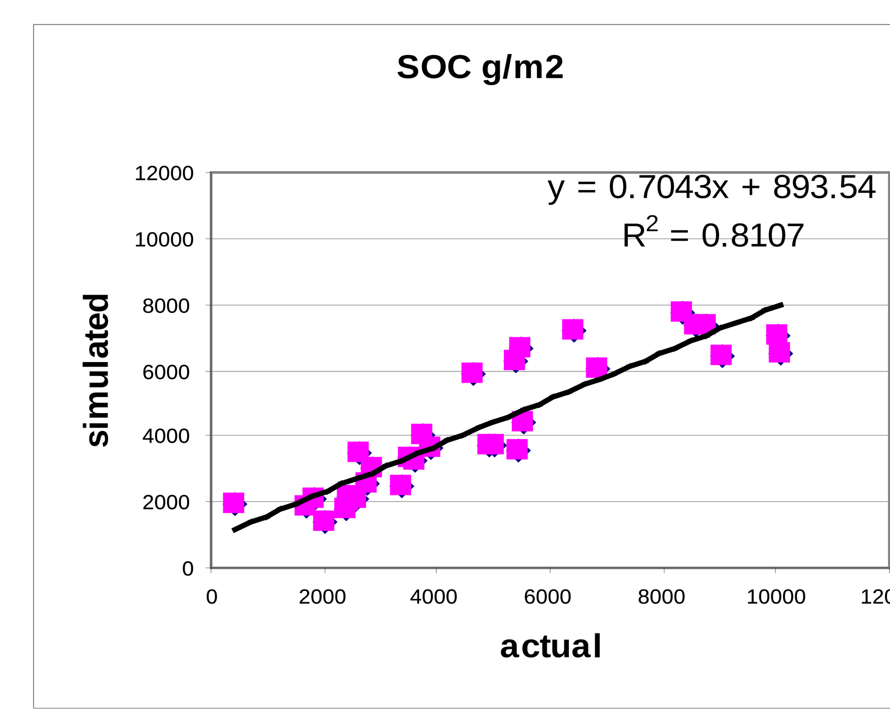
Figure 3. Eurasia displays highly dynamic source-sink dynamics associated with climate variability and to certain extent to land use changes associated with modifications of cropland abandonment and grazing intensity.

Ecosystem Dynamics

The Century 4.0 model was used to simulate long-term dynamics of soil organic matter and plant productivity. 37 sites, which represent different ecosystems such as the forest steppe, the steppe, the Altai mountains and the Gobi desert, have been selected for the study. Simulated and observed C and N had *r2*=0.81 and 0.82, respectively. Interannual coefficient of precipitation variation was less than 33 % in the northern part of the country and higher than 33 % in the Gobi desert steppe. Aridity index which is defined as ratio of annual precipitation to potential evapotranspiration, is declining from the north to the south of the country due to decreasing precipitation and increasing temperature. The highest rain use efficiency of grasses is the steppe and the lowest in the desert ecosystem. *r2* between simulated and measured aboveground peak biomass was 0.51.

Under recent past 40 years climate change soil carbon and aboveground peak biomass. Soil carbon amount increased by 1.96 % (about 134 gC/m2) in the forest steppe, 1.38 % (51 gC/m2) in the steppe, 1.42 % (42 gC/m2) in the Altai mountains and decreased by –2.44 % (about - 46 gC/m2) in the Gobi desert region. Soil carbon changes were explained by mainly effect of temperature increase on decomposition. In the Gobi desert steppe, decomposition rate is low because of water shortage and warming had negative results on soil carbon pool. Soil organic carbon changes did not have significant effect on aboveground peak standing biomass trend. Aboveground peak biomass was influenced mostly by rainfall changes past 40 years. Because of precipitation decline, aboveground peak biomass decreased by 30.8% (-35 g/m2) and 13.2% (-14 g/m2) in the forest steppe and the steppe, respectively. Increased precipitation had direct effect on aboveground peak biomass which raised by 47 % (15 g/m2) in the Altai mountains and 30.8 % (7 g/m2) in the Gobi desert.





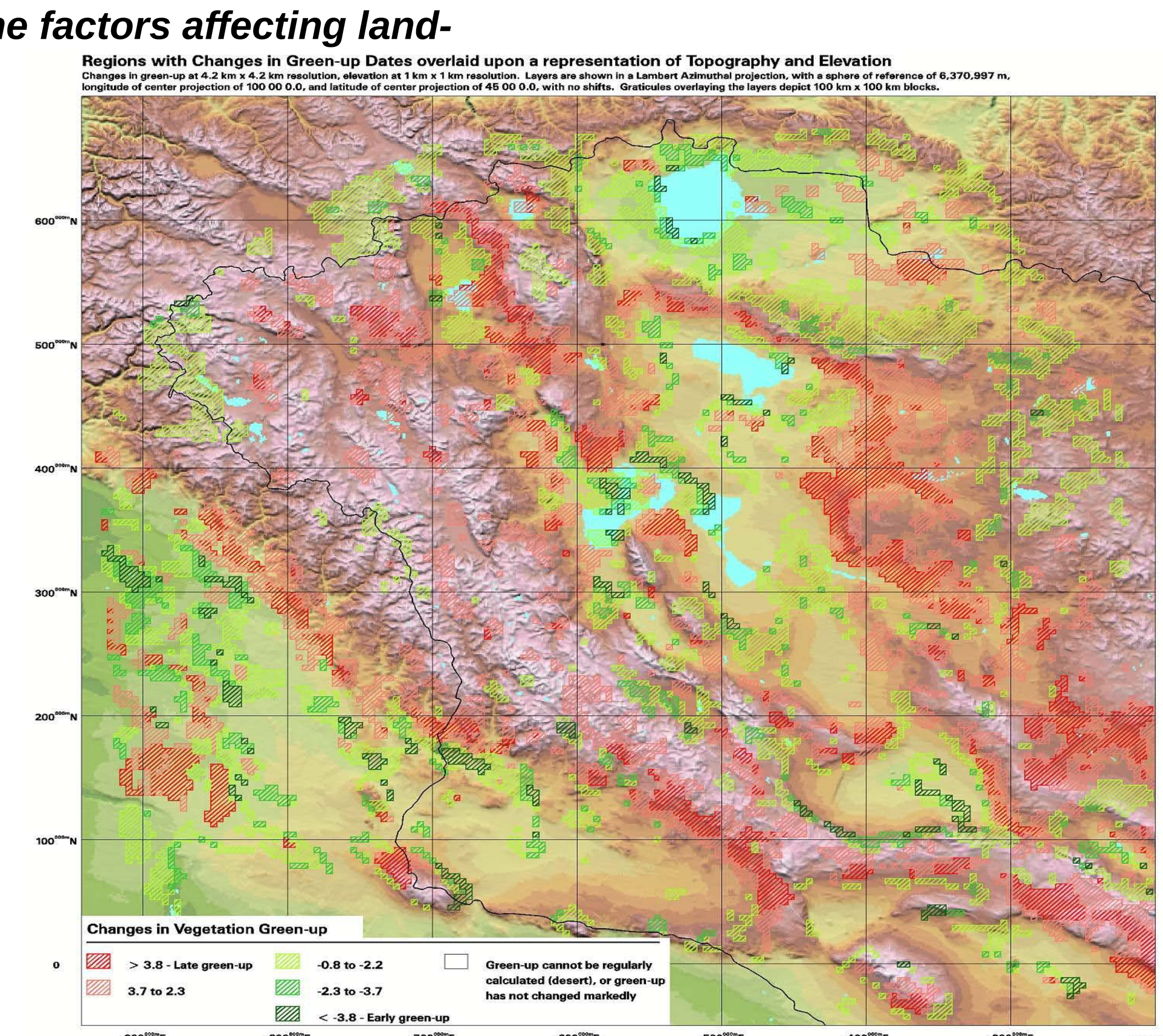
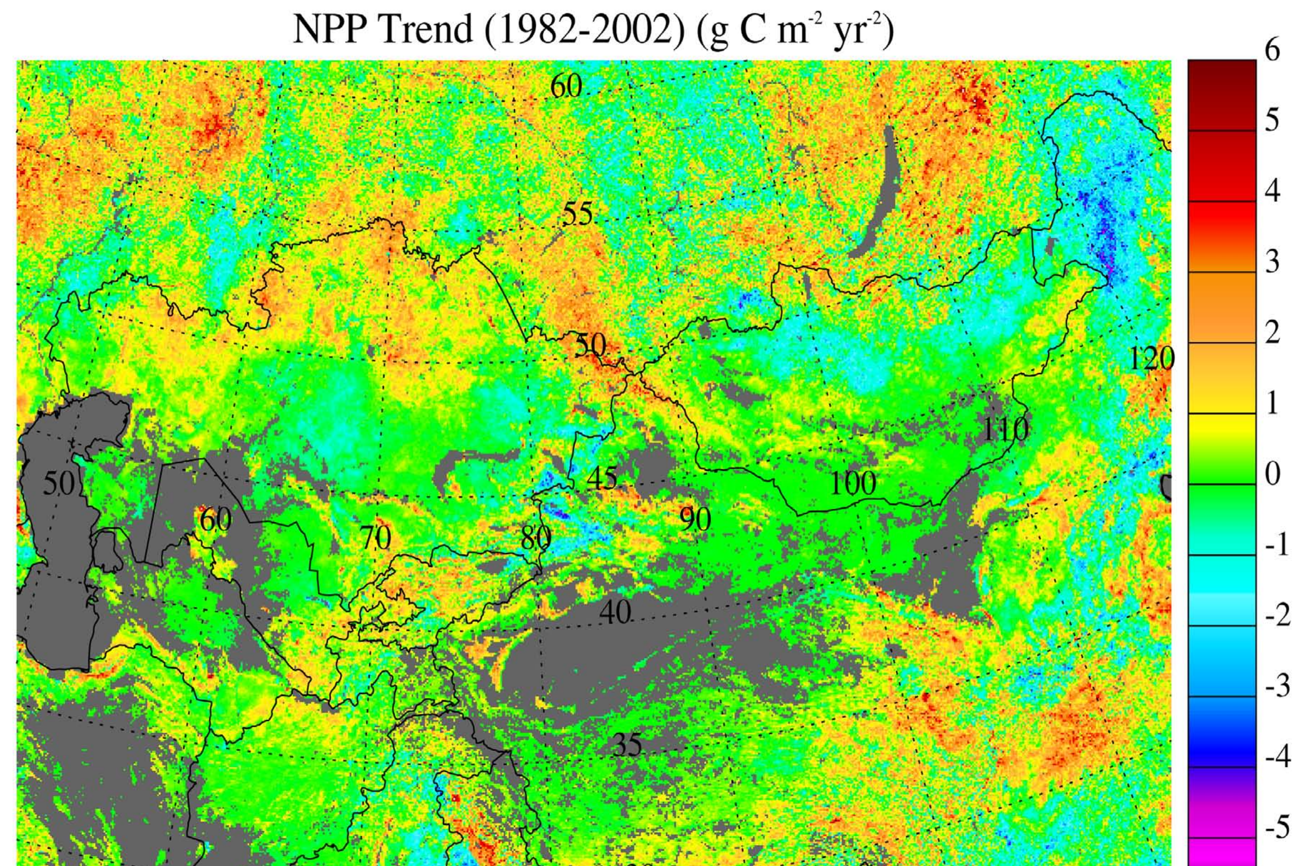
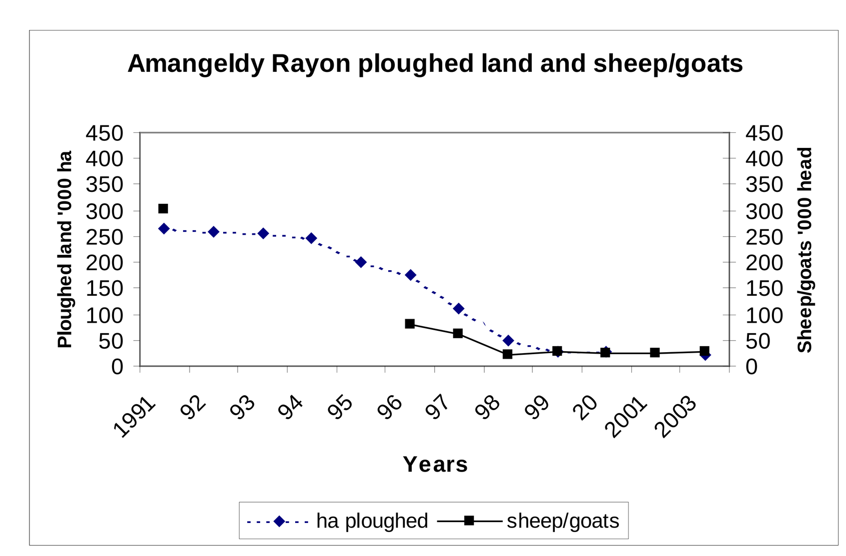


Figure 4. Change in onset of green-up in a sub-region of Eastern Mongolia.

NPP Trend (1982-2002) (g C m^{-2} yr^{-2})





Land Use Trends. Agricultural trends in region has dropped dramatically due cessation of government subsidies and other agricultural central planning amenities. Fertilizer inputs, fuel For farm implements, and access to fodder have all declined In the past 10 years. Typical of the cropland area in Central Asia and Mongolia we observe dramatic decline in crop area, however for livestock densities, Central Asia has experienced dramatic changes and whereas Mongolia has experience increased numbers. This difference has been related to their ability to enter the free market system.

Productivity of the region is complicated by the land use factors and defining a general pattern of trends is not currently possible. NPP trends in the region indicate areas of increases and decreases and these do not always follow known climate patterns. So what is implied is that land use and climate interactions need to be studied, the current project is continuing to further this research.

Conclusions

Climate change and livestock density have contributed to decline in steppe productivity over the past 40 years. The last decade has endured both dramatic increase in temperatures and grazing intensity. An estimated 25% decline in carrying capacity for the steppe ecosystems has been projected. This decline in carrying capacity will have a major impact on the future livelihood of the pastoralists in the region. This decline in carrying capacity is associated with climate change and changes due to increased grazing pressures in the recent decade.

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