Pasture estimating with climate change over Mongolia using climate and NOAA/NDVI data

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Abstract: Geographical position and associated climatic influences can be a negative environmental condition that affects sustainable use of land resources, especially pastoral livestock production. Vegetation condition of the country is sensitively changes upon climate changes and human impacts. Within last 60 years data the annual air temperature has increased in 1.66 degrees in average and the total precipitation amount had almost no change.

The main goal of this work is to relate climate change within last 20 years with pasture condition, estimated by NOAA/NDVI data set.

Keywords: pasture, climate change, livestock, biomass, correlation.

1. Introduction

In this paper we included some results of integration of pasture vegetation monitoring using NOAA/NDVI data and climate data for whole territory of Mongolia.

Mongolia, with its nomadic animal husbandry or livestock farming is one of the most dependent countries on nature and climate condition. Today the number of livestock reached 26 millions a head and the pastureland occupies more than 80 per cent of the territory, which is main source for animal grazing for whole year, as forage.

2. Used data and methodology

The NDVI (normalized difference vegetation index) dataset is unique in that it is global, multi seasonal, multi annual, and multi spectral. In this study we have used 10 days composite NOAA/NDVI 8 km resolution data from 1981 to 2001. According to the common global warming problem we have analyzed last 60 years climate data for whole Mongolia. Pasture plant biomass data measured at the meteorological/agro-meteorological stations and biomass data simulated by CENTURY model, are used to estimate pasture productivity for whole country.

We have analyzed 40 years data* of more than 60 stations and defined average biomass of different ecosystems.

In this study we have established the integration of remotely sensed data with ground observation data and calculate their correlation.

3. Climate changes

Climate change represents an important additional stress to the many ecological and socio-economic systems already affected by pollution, increasing resource demands and no sustainable management practices. The most vulnerable systems are those with the greatest sensitivity to climate changes and the least adaptability (IPCC, 1995).

The Mongolian climate characterizes by long lasting cold winter, cool summer, small precipitation, high temperature fluctuation, and relatively high number of sunny days a year. There are 4 sharply distinguishing seasons with different months in respect to climate.

According to the analysis of climatological data within last 60 years, the annual mean air temperature has increased by 1.66°C. The seasonal temperature trends estimated differently as, it increased by 3.61°C in winter, 1.4 – 1.5°C in spring and autumn, and -0.3°C in summer (L. Natsagdorj, 2002).

The temporal and spatial distribution of precipitation is completely different and its amount is generally insufficient (50-450mm/year). Precipitation amount decreases from North to South and from East to West, and about 85% of total precipitation falls in warm season from April to September and 50-60% of which falls in July and August.

4. Pasture productivity

There are 2600 species, but only about 600 species eaten by livestock. Some research showed that the total pasture capacity of the country is 50 to 60 million sheep

* Pasture plant monitoring observation has started since 1964. Pasture plant phenology and biomass data of 64 stations with the longest time series data were prepared and analyzed. Pasture plant observation is done in the fence.

unit. Today, the current total livestock reached to 72 million sheep unit and pasture area reduced by 5 – 6 millions ha because of urbanization, mining industries, and tourism. The average livestock density is 54 animals per 100 ha in the country and different in different natural zones.

Plant productivity of the Mongolian arid and semi arid pasture has high variability as precipitation. Mean of peak standing biomass varies from 100 to 1000 kg/ha, decrease from the North to the South.

Pasture biomass measurement is crucial to estimate forage resource. As defined, the peak biological biomass is 1050-1500 kg/ha in the high mountains, 1150-1940 kg/ha in the forest steppe, 650-1300 kg/ha in the steppe and 290-380 kg/ha in the desert steppe (Tserendash S.).

According to the study, average peak standing biomass is 590 kg/ha in the forest steppe, 300 kg/ha in the steppe, 220 kg/ha in the desert steppe and 170 kg/ha in the Altai Mountains and the desert (Table 1).

Table 1. Pasture biomass, 100 kg/ha

	month_day									
ecosy stem	6_04	6_14	6_24	7_04	7_14	7_24	8_04	8_14	8_24	peak biomass
the forest steppe	1.3	1.9	2.5	3.0	3.6	4.3	4.9	5.3	5.3	5.9
the steppe	1.2	1.5	1.8	1.8	2.0	2.3	2.7	2.8	2.8	3.0
the Altai mountains	0.7	0.7	0.9	1.0	1.1	1.3	1.3	1.4	1.3	1.7
the desert steppe	0.7	0.8	1.0	1.0	1.2	1.4	1.5	1.6	1.7	2.2
the desert	0.6	0.7	0.8	0.9	1.2	1.2	1.4	1.5	1.4	1.7

The study showed that pasture productivity has decreased under climate change. For past 40 years pasture biomass has reduced by 20 to 30 percent.

According to the ecosystem model Century, average spring potential biomass was estimated as 27-50 g/m2 in the forest steppe, 15-33 g/m2 in the steppe, 5-13 g/m2 in the Altai mountains and 3-6 g/m2 in the Gobi desert.

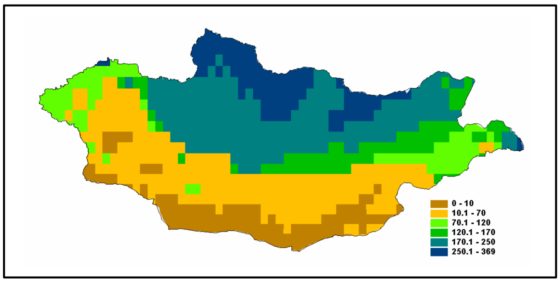

Fig. 1. Peak biomass, simulated by Century model, g/m2

From this figure we can distinguish summer peak biomass from 1 ts/ha to 25 ts/ha in different natural zones. In fact this figure could directly present the natural zones of the country. The total pasture carrying capacity∗ was estimated as 44.5 million sheep unit based on average observed biomass. Based on the decreasing trend of peak biomass by 20-30 %, the total pasture capacity was calculated as 32.6 million sheep unit. Past 40 years the total pasture carrying capacity was drop down by 27 % because of biomass decrease.

∗ Pasture carrying capacity was calculated by pasture area, biomass, and annual intake of sheep. Depending on ecosystems, 55 to 65 % of total biomass is consumed by livestock.

5. Monitoring of pasture condition from space

Among several types of satellite data available for monitoring of global scale and NOAA AVHRR data has been selected primarily because of its high frequency, wide coverage for one pass and low cost compared to high resolution satellite data.

NDVI value derived from NOAA/AVHRR has becoming the main tool to estimate and monitor vegetation dynamics for whole territory of Mongolia over long duration.

According to the daily or 10 days NDVI composite images we can determine the temporal and spatial vegetation changes i.e. onset, growing pick and senescence time of vegetation growth. From the general dynamics of pasture condition we could say that better grazing time for the pasture animals begins from earlier May to latest October till suffering full snow coverage and the best grazing time is too short as, from July to August.

From NDVI data we can assess seasonal (by 10 days and monthly) and long term vegetation dynamics (Fig. 2 and Fig. 3).

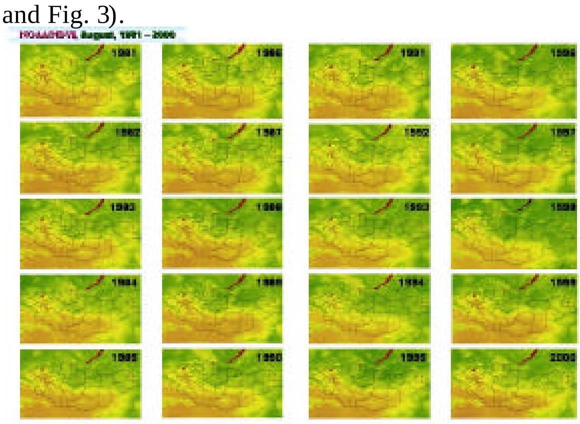

Fig. 2. Long term NDVI dynamics (August, 1981 – 2000)

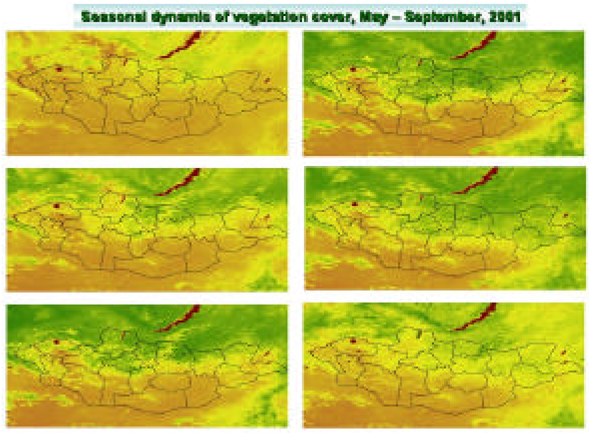

Fig. 3. Seasonal NDVI dynamics (May – September, 2001)

There are several types of ecosystem, like high mountain, mountain taiga, forest steppe, steppe, desert steppe, and desert, which are completely different from each other. By time series analysis of NDVI data, from 1981 to 2001 and calculated long term mean values for each month and for all year of whole Mongolia within various natural zones.

According to the NDVI deviation from the mean in July and August there are 2 kinds of trend. From 1981 to 1994-1995 NDVI deviation increased 0.33-1.1 values a year and up to 2001 it decreased stronger than increase and it reached – 0.87 to -2.78 values a year (Fig. 4). We need to distinguish above statistical results could present only some climate variability or pasture degradation related with increase of livestock numbers and human activities.

As estimated, that the more than 50% of total precipitation falls in July and August, we correlated with NDVI dynamics (Fig. 5) and these values have been highly correlated within last 20 years (r = 0.51-0.64). This result could approve the strong influence or strong role of precipitation to vegetation growth.

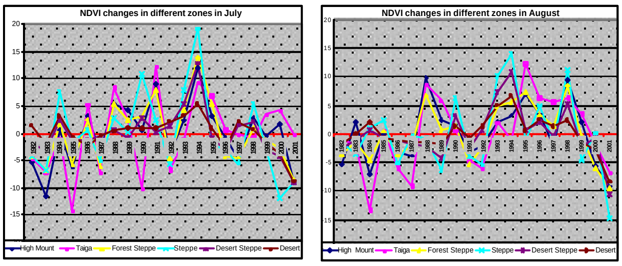

Fig. 4. NDVI changes in different zones

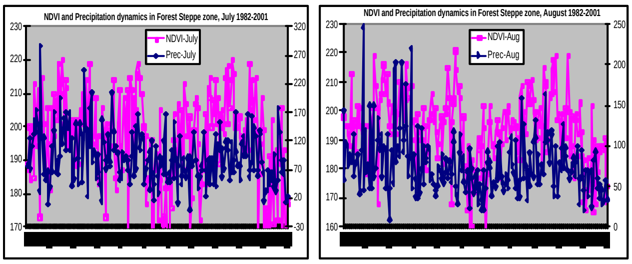

Fig. 5. NDVI and Precipitation dynamics, July – August, 1982 – 2001

The mean NDVI values for each natural zone derived from time series analyzed NDVI data of 1981-2001 and respective biomass dynamics are illustrated in Fig. 6.

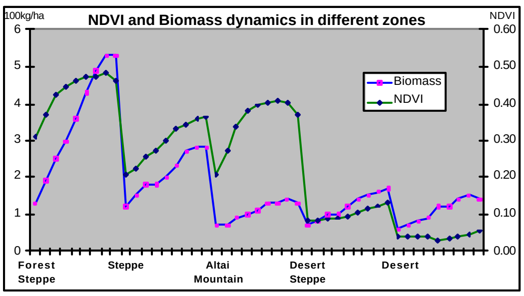

Fig. 6. Mean NDVI and pasture biomass dynamics in different zones.

In general, the NDVI and pasture biomass are following the similar dynamics The averaged by different zones, correlation coefficients between NDVI and simulated biomass was higher than correlation between NDVI and measured biomass both inside fence and in open pasture and these values reached higher in July than in August. The comparison of correlation between NDVI and both fenced and open measured biomass showed that, the correlation NDVI and open measured biomass was less than first one in some zones. But the data quility and data range could influnce to this correlation.

6. Conclusion

Pasture vegetation condition highly depends on both of natural factors and human activities. The natural factors are consequent increase of air temperature (1.66°C per 60 years), insufficient amount, and various temporal and spatial distribution of annual precipitation over the territory and increase of occurrence of natural disasters. Within negative human impacts on pasture vegetation, included increase of livestock number, heavy overgrazing of pasture and mining and etc. All above factors are cause reduction of vegetation biomass in different natural zones of Mongolia.

By NDVI data of NOAA satellite data with low resolution and high frequency, could be estimated not only the pasture vegetation condition and also it could be related with both of climate and biomass data.

The traditional measurement of biomass was done since 1940s and used biomass data simulated by CENTURY model and both biomass data were correlated with NDVI data. The correlations between vegetation biomass, simulated by above model and NDVI values gives higher results than correlation between NDVI and observed vegetation biomass data, collected by agrometeorologists at certain meteorological stations of different zones. This correlation coefficient in July reached the maximum value in each zone.

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