LONG TERM SATELLITE DATA APPLICATION FOR PASTURELAND BIOMASS MONITORING IN MONGOLIA

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ABSTRACT:

In this paper we included the results of new approach to estimate pasture biomass amount for livestock fodder and pasture carrying capacity using both of remote sensing and in-situ data over whole territory of Mongolia. According to the ecosystem model Century, an average spring potential biomass was estimated at 27-50 gm^{-2} in the forest steppe, 15-33 gm^{-2} in the steppe, 5-13 gm^{-2} in the Altai mountains and 3-6 gm^{-2} in the Gobi desert and the result showed that in past 40 years the total pasture carrying capacity was drop down by 27 % because of biomass decrease (Bolortsetseg et al, 2002). The pasture biomass and carrying capacity values can be derived from high temporal resolution FY-2C geostationary satellite data using Energy and Water Balance Monitoring System (EWBMS) developed by EARS Company, the Netherlands.

1. INTRODUCTION

Mongolia has the nomadic animal husbandry which directly dependent on climatic situation over a year. There are 2600 species in Mongolian pasture, but only about 600 palatable species are available for livestock and the total pasture capacity of the country is 50 to 60 million in sheep unit (ER, 2001). Nowadays, the current total livestock reached to 44.2 million heads or 72 million in sheep unit and pasture area reduced by 5–6 million ha because of urbanization, mining industries and tourism.

Pasture biomass measurement is important to estimate forage resource. Many scientists have separated the natural zones into 6 types such as, high mountain, mountain taiga, forest steppe, steppe, desert steppe and desert zones.

These zones are different not only by geographical location but also by pasture biomass its fodder resources. For example, ScD. Tserendash has estimated the pasture biological biomass by each zones in summer season as, 10.5-15.0 ts/ha in high mountain zone, 11.5-19.4 ts/ha in foresst steppe, 6.5-13.0 ts/ha in steppe and 2.9-3.8 ts/ha in desert steppe zone respectively. But he estimated that it can reach upto 28.6-39.7 ts/ha in the meadow flood plain pasture.

The previous remote sensing based technology for pasture biomass estimation was done (Erdenetuya M., 2004) using long term NOAA/NDVI data with comparison of biomass measurements data at the meteorological stations.

The Energy and Water Balance Monitoring system (EWBMS) software has been developed as part of the project "National Geoinformation Centre for Natural Resource Management" framework. Satellite imagery from the geostationary satellite FY2C is used for near real time monitoring and mapping of rainfall, radiation and evapotranspiration. Subsequently, spatially continuous information on winter grazing conditions, drought indices and pastureland conditions can be generated. The output of the EWBMS system is used for development of a decision support system for pastureland management.

Within this work we have selected the methodologies applications for pasture biomass and as well as its carrying capacity estimation based on different satellite imageries.

2. DATA AND METHODOLOGY

2.1 Above Ground Vegetation Biomass Assessment by NOAA Satellite Data.

2.1.1 NOAA/NDVI and its change over the years. Natural green vegetation has become the main source for keeping and managing the sustainability of ecology and for producing a healthy environment of feeding human society through hay and pasture based livestock husbandry.

For pasture biomass estimation we have used both of NDVI (normalized difference vegetation index) derived from NOAA satellite data (NASA Pathfinder source, 1982-2003) and ground measurement data from 47 meteorological stations and several of ground measurements from other sources.

The parameter used most frequently for vegetation monitoring with NOAA-AVHRR data is the Normalized Difference Vegetation Index (NDVI), which is derived from the visible red (RED) and near-infrared (NIR) channels:

$$NDVI_{NOAA} = (RED - NIR) / (RED + NIR) \qquad (1)$$

In equation 1, RED is the reflectance measured in the visible channel, and NIR is the reflectance measured in the near-infrared channel.

NDVI is generally recognised as a reliable index of ground vegetation cover. There are many approaches to estimate long term changes of pasture vegetation cover in order to assess the natural factors to the global vegetation coverage.

The approach for NDVI change estimation is use of the standardized of the long term vegetation index (SVI) for certain period and it utilized by following expression as,

$$SVI(i,j,t)=[NDVIcur(i,j,t)–NDVIav(i,j,t)]/\sigma(i,j,t) \qquad (2)$$

where, $SVI(i,j,t)$ is a standardized NDVI index of each pixel (i is row number, j is a column number) at certain time (t). After calculating SVI of each pixel for identification of linear trend the whole image has been resample in to grid of 0.5 by 0.5 degree cell.

2.1.2 The method for biomass estimation through NOAA/NDVI: The archived NDVI, ground observation and simulated biomass data and other materials have been used for the development of a method for biomass estimation in each natural zone. All this data has been integrated with NDVI and the results of the analysis reveals that the NDVI is highly correlated (r=0.45-0.70) with the simulated biomass for the whole of Mongolia as well it is also highly correlated with ground observation (r=0.867) biomass data. The correlation between NDVI and biomass observation in grazed pasture was 0.22-0.64 on average. So the additional observation data has been used to prove the accuracy of the results.

Based on the materials obtained, the linear regression expressions for each natural zones differs, which are suited with the satisfactory requirements of mathematic-statistical correlations, i.e. by the statistic analysis requirement the correlation coefficient would be enough if r > 0.40 depending on the data range as use on 22 years data.

2.2 Above Ground Vegetation Biomass Assessment by EWBMS with FY-2C Satellite Data

The Energy and Water Balance Monitoring System consists of a number of steps that sequentially have to be carried out in order to obtain the final drought, pastureland and winter grazing condition products.

Spatially continuous maps of rainfall and energy balance components are important intermediate products. EWBMS products are being validated by the ground data. In this work, the decadal pasture biomass monitoring data of about 120 meteorological stations of Mongolia were used.

2.2.1 Pasture Monitoring System The Pasture Monitoring System simulates pasture growth with daily radiation, temperature and relative evapotranspiration data from the Energy Balance Module.

Four different output products can be generated with the Pasture Monitoring System which shows the geographical distribution of:

➢ Actual biomass: the pasture absolute yield (kg/ha) as the amount of aboveground green biomass in dry matter.

➢ Relative biomass: the pasture relative yield (%) or the actual biomass relative to the aboveground green biomass of pasture that would be attained without water limitations to the plant.

➢ Biomass available for grazing: the daily optimum amount of biomass (kg/ha) that is available for grazing.

➢ Pasture carrying capacity: the number of cattle (0.1 Sheep Units/ha) that the pasture can support based on the information in the Biomass available for grazing files.

2.2.2 Alternative Statistical Method:The relative yield is defined as the actual, water limited yield relative to the maximum, non water limited yield:

$$RY=Pact/Ppot *100 (\%) \qquad (3)$$

where:

RY : the relative yield

Pact: the actual, water limited yield

Ppot: the yield that would be obtained without water limitation (relative evapotranspiration 100%)

To calculate the actual pasture biomass of a certain area, the relative yield is multiplied with the average historical yield of that area:

$$Yield_{2007} =(RY_{2007} /RYhist) * Yieldhist \qquad (4)$$

where:

RYhist : the relative yield obtained with historical satellite images, averaged over a number of years

RY2007 : the relative yield obtained with satellite images of 2007

The method can be applied to grazed or ungrazed areas and it is potentially the best method to estimate the pasture biomass of the ongoing growing season over different natural zones (Figure 1). A fair number of satellite imagery and historical data on pasture biomass (Aimag, Soum or Bag level) however are needed for this.
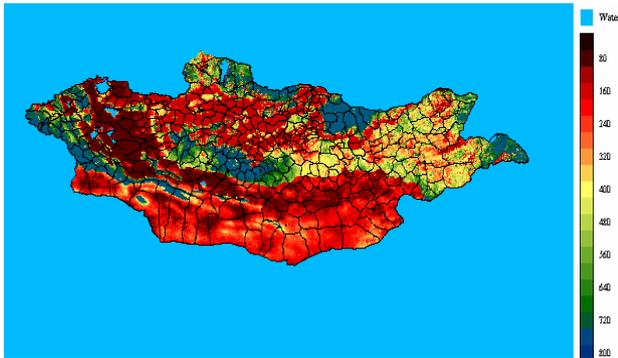
Figure 1. Actual pasture biomass map of Mongolia, August 2007 (kg/ha)

2.2.3 Pasture Carrying Capacity: The calibrated pasture models for each natural zone have the option to introduce a certain amount of biomass that is consumed by the herds. The pasture carrying capacity can be estimated by varying the amount of consumed biomass in the model and monitor the response of the pasture biomass. An example for this relationship (2.1 kg/ha) in the Steppe zone is given in Figure 2.
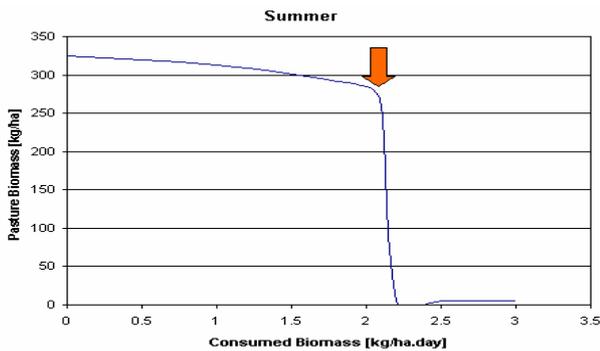

Figure 2. Determination of the carrying capacity (kg/ha)

The biomass consumed by the cattle was varied from 0 to 3 kg/ha day and the response on the pasture biomass (kg/ha) plotted. The figure shows that biomass consumptions from 0 to 2 kg/ha have only a very limited influence on the Steppe pasture biomass (decrease of 67 kg/ha).

2.2.4 Pasture Consumption: An estimation of the amount of biomass that is actually consumed by the cattle is based on the intake of one sheep unit and the cattle numbers during the period of interest. Consumption of one sheep unit is based on a 60 kg live sheep weight that eats 3% of its body weight a day at a maximum intake of 1.9 kg/SU day and 657 kg/SU.year. Intake per SU is 1.9 kg/SU.day in summer season, 1.1 kg-spring, winter season and 1.6kg-autumn.

3. RESULTS AND ANALYSIS

3.1 NOAA/NDVI Change Trend

The approach for estimation of the NDVI change trends as, increasing and decreasing, which calculated by equation 2, is illustrated in Figure 3.

As shown in Figure 3, in third 10 day of July mostly in high mountain regions or 31% of whole territory of the country NDVI values had increased (green color) and in all other parts (69%) NDVI had decreased (yellow color) or had almost no change (white color) within 22 years. The pasture vegetation biomass has been calculated after the illumination of forest coverage (white color in the Figure 4) and the biomass values have been classified in 5 types for visualization and monitoring of changes in area.

The calculated biomass values and the observed biomass have correlated highly and its correlation coefficient has reached to r=0.814.
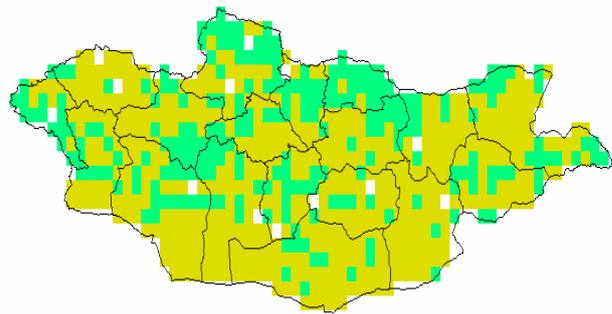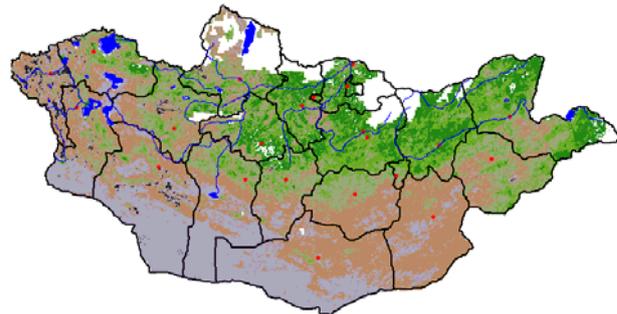

Figure 3. NDVI change trend map (July 1982-2003)

Figure 4. Biomass map of last 10 day of July 2003

3.2 Pasture Monitoring System Products

We made the pasture model validation on each natural zone using the decadal data of June-September, 1999, 2000, 2001, and 2006. Validation results were based on 548 biomass data of 37 stations in steppe zone (Figure 5) and the correlation was quite good (R2 = 0.71).

We compared the some results of the soum averaged yield 2007 (Figure 6) and ground point biomass of meteorological stations. There are some differences between several stations' data, but, generally, difference between the satellite data and the ground data is not much.

Pasture carrying capacity of 2007, estimated by EWBMS, was averaged by soums (Figure 7). Pasture carrying capacity is between 0.3-1.0 SU/ha in Western and Gobi-Desert region of Mongolia. In the Gobi-Desert region, the pasture biomass is low, but there is much pastureland area and relatively few cattle numbers.
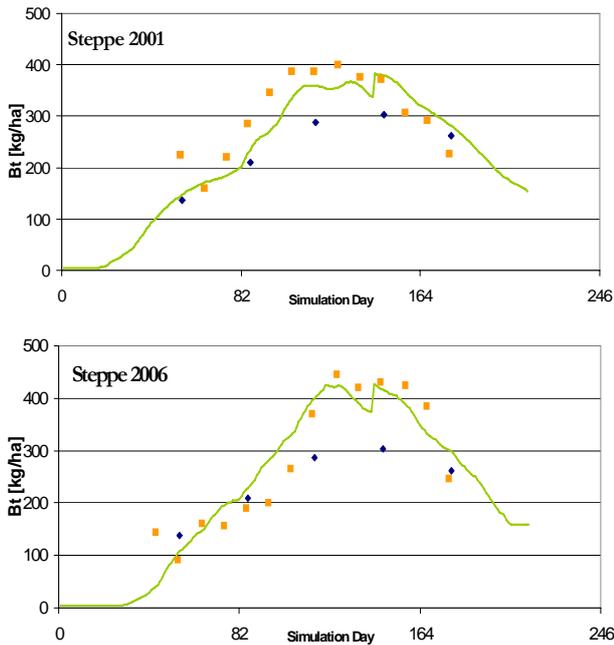
Figure 5. Pasture model (Steppe) Green-pasture model, yellow ungrazed biomass, blue-grazed biomass

The figure shows that pasture carrying capacity is around 1.7-2.1 SU/ha in Eastern region because the biomass was low this year.
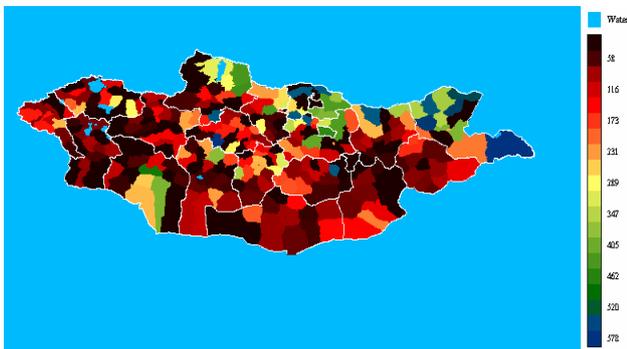

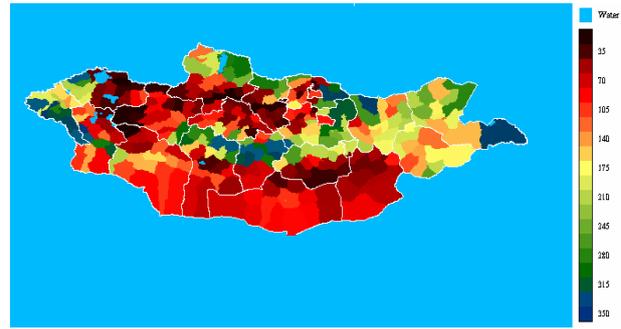Figure 6. Pasture biomass map, kg/ha, Aug 2007 (Soum averaged),

Figure 7. Pasture carrying capacity map, SU/ha, 2007 (Soum level)

CONCLUSION

1. The long term NOAA/NDVI value changes could indicate the pasture degradation condition (69% of decrease) due to global warming and overgrazing.

2. The methodology to estimate pasture biomass through NOAA/NDVI in different natural zones had been approved and generating 10 daily based products during growing season.

3. EWBMS and Pasture Monitoring sub system is very important in Mongolian pastureland management and for early warning drought and dzud phenomena.

4. The Pasture Monitoring System has been implemented, but we still need further validation work for basic products of EWBMS and other application products as well.

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