# MAPPING SUMMER TIME PASTURE AMOUNT IN NORTH-CENTRAL MONGOLIA

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**ABSTRACT:** Providing up-to-date information about pasture amount distribution can help nomadic herders in Mongolia make timely decisions when and how they can make the next move — particularly in summer grazing season. In an attempt to develop a procedure for rapidly producing maps that depict summer time pasture amount distribution with frequent observing satellite data, we linked ground pasture amount and MODIS vegetation index (VI). Our previous study combining ground vegetation sampling and *in situ* spectroradiometer measurements indicated that the green pasture amount can be estimated to a satisfactory level of accuracy using NDVI values. Further study showed that *in situ* spectral measurements agreed well with high-resolution FORMOSAT-2 image data properly corrected for atmospheric attenuation. In this study, we cross-validated MODIS NDVI with a corresponding FORMOSAT-2 NDVI dataset (24 by 24 km) in Bornuur district, our test area in north-central Mongolia. The study site is located in the Forest-Steppe ecological zone. Results signaled that correlation coefficient between the corresponding NDVI values to be 1.03 with a R-square 0.53 (n = 9457). After excluding forest cover, which is the only obvious non-pasture land cover in much of Mongolian territory, we estimated that the average pasture amount to be approximately 1.25 ton/ha in Bornuur district (77,087 ha), Tuv Province in the summer 2009. This corresponds well with documented tabular statistics while providing adequate spatial variability in distribution. While more work is on the way to account for different pasture cover types, we expect this mapping procedure can be extended into the neighboring pasture lands in the same ecological zone.

## 1. INTRODUCTION

Mongolia is a country mainly based on nomadic animal husbandry with the territory of 1,565,000 km². Its animal husbandry depends strictly on weather condition. The amount of summer time pasture available to herders limits the optimal number of grazing animals in summer time as well as the amount of future fodder resources to be harvested for winter time. The combination of accurate estimation of pasture resources and a good understanding of current pasture utilization leads to compiling a better information about the pasture/fodder resources in Mongolia.

Remotely sensed satellite data have commonly been used for estimating spatial distribution of pasture resources. In an effort to estimate the summer time pasture amount in north-central Mongolia, we carried out an intensive ground observation and confirmed a close relation between the above-ground pasture biomass and spectral data captured by a spectroradiometer (Batbileg, 2008; Hirano *et al.*, 2008). The objectives of this study are to examine if the previous results can be extended to the neighboring pasture lands, and, if so, to develop a procedure to produce maps depicting pasture biomass and distribution — in a timely manner. In order to do so, MODIS, which has relatively coarse resolution but frequent earth observation capability is put on the test. We tried to link the ground measured biomass to a high-resolution satellites' spectral data further onto those from frequently observing satellite, MODIS.

## 2. THE STUDY AREA

The study is area is located in the Forest Steppe zone in the north-central Mongolia, centered around 48°40'30''N and 106°15'55''E with approximately 24 km × 24 km in size. The study area contains Mongolian State University of Agriculture (MSUA)/Japan International Research Center for Agricultural Sciences (JIRCAS) grazing experimental site (23ha). We have accumulated a detailed ground data of pasture biomass over the last 4 years since 2006.

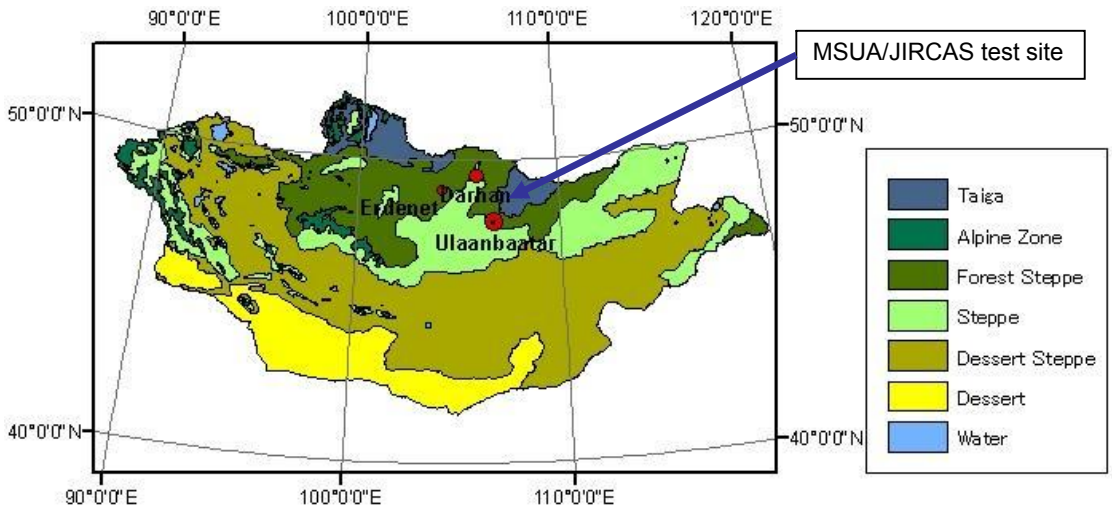


**Figure 1.** The location of the study area and ecological zones of Mongolia.

## 3. DATA AND METHODS

We used datasets from three different satellites in this study, 1) MODIS, 2) Taiwan's high-resolution satellite FORMOSAT-2, and 3) Landsat, respectively. First, we obtained a series of MODIS Land product (250 m datasets with a 16-day composite) up to May 2010 from the USGS. We carried out a series of preprocessing before calculate a time-series MODIS normalized difference vegetation index (NDVI) data with a geographic coordinate system cast on World Geodetic System of 1984 (WGS84).

Second, we used an orthorectified Landsat data (Path/Row: 132/027, acquired on August 24, 2000) to evaluate the positional error of the reprojected MODIS pixel on the ground. NASA has

instituted these global orthorectified Landsat dataset with a known positional accuracy — root mean square error (RMSE) of ±50m (Tucker *et al.*, 2004).

The FORMOSAT-2 image data (2 m PAN, 8 m MS) acquired on August 11, 2009 captured our grazing experimental site and the vicinity (23 × 23km). These image data were both geometrically and atmospherically corrected in our previous work. The NDVI values computed from this image data agreed well with those from spectroradiometer and the ground pasture biomass amount (Hirano *et al*., 2008).

Next, we selected the MODIS NDVI data that temporary corresponded with the FORMOSAT-2 NDVI data (August 11, 2009). Positional error inherent in the MODIS data were taken into account by spatially averaging the corresponding FORMOSAT-2 NDVI pixels by using MODIS pixels fell in the buffer zone as describe in Figure 2. One-on-one NDVI correspondence (MODIS and spatially aggregated FORMOSAT-2) resulted in a scatter plot, and relevant coefficient of correlation with the coefficient of determination ($R^2$).

In order to demonstrate if the MODIS NDVI can provide reasonable estimate of ground pasture biomass, we applied the equation we have established in our previous study — using ground biomass sampling measurements and spectroradiometer measurements — to MODIS NDVI data (August 2009) of Bornuur soum. In doing so, we excluded the forest cover, which is the obvious non-pasture land cover in much of Mongolian territory.
The equation used in this study is as follows:

$$\text{Ground pasture biomass [ton/ha]} = (211.5 \times \text{NDVI} - 5.2356) / 100 \quad (1)$$

## 4. RESULTS AND DISCUSSION

### 4.1 Geolocation accuracy assessment of MODIS data

Detailed cross-examination of 53 well-distributed random points across the orthorectified Landsat image and the corresponding MODIS NDVI data (September 14, 2000) using ESRI ArcGIS 9.3 software yielded the average shift of 166m. This means the MODIS NDVI pixel can be misplaced as much as 150+m (approximately 0.6 pixel) relative to the orthorectified Landsat images. Considering that the orthorectified Landsat images themselves are accurate in position to the RMSE of ±50m, the MODIS NDVI pixel can be up to 200+m (0.8 pixel) misplaced from its actual location on the ground. Since the shift directions were not uniform and appeared random, any shift could be expected to be 100-200m (166m ± 50m). We incorporated these potential shift values by clipping out the corresponding high-resolution satellite image data to be compared with the buffered MODIS pixel.

### 4.2 Cross validation of MODIS NDVI and FORMOSAT-2 NDVI

As mentioned above, in order to take into account for MODIS pixel shift, we generated a 100m buffer (which means expanding the pixel size from 250 × 250m up to 450 × 450m) on each MODIS NDVI pixel (Figure 2). For each expanded MODIS NDVI pixel, we spatially aggregated the corresponding high-resolution FORMOSAT-2 pixels.

The result is summarized in the scatter plot (Figure 3). With 9455 corresponding sample points, the correlation between the MODIS and FORMOSAT-2 NDVI proved acceptable (coefficient of correlation being nearly 1.0 with $R^2$ of 0.53). The result indicated that any MODIS NDVI values can be considered as the spatial aggregation of the embedded high-resolution satellite NDVI values, and vice versa. Therefore, we conclude that ground measured biomass can indirectly be linked to MODIS NDVI.

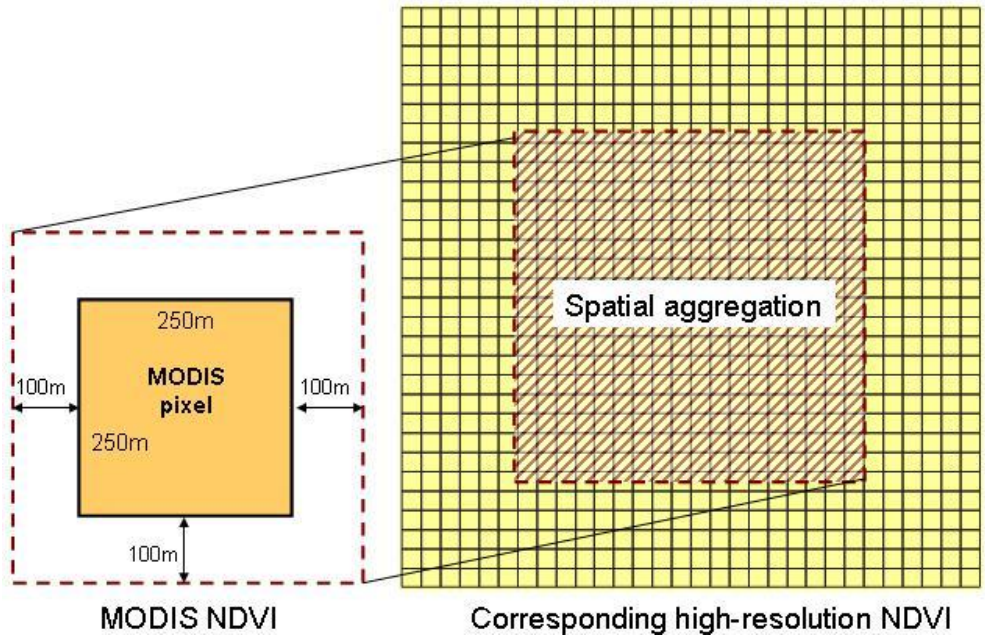


**Figure 2.** Conceptual diagram of clipping operation that takes into account for MODIS pixel positional error.

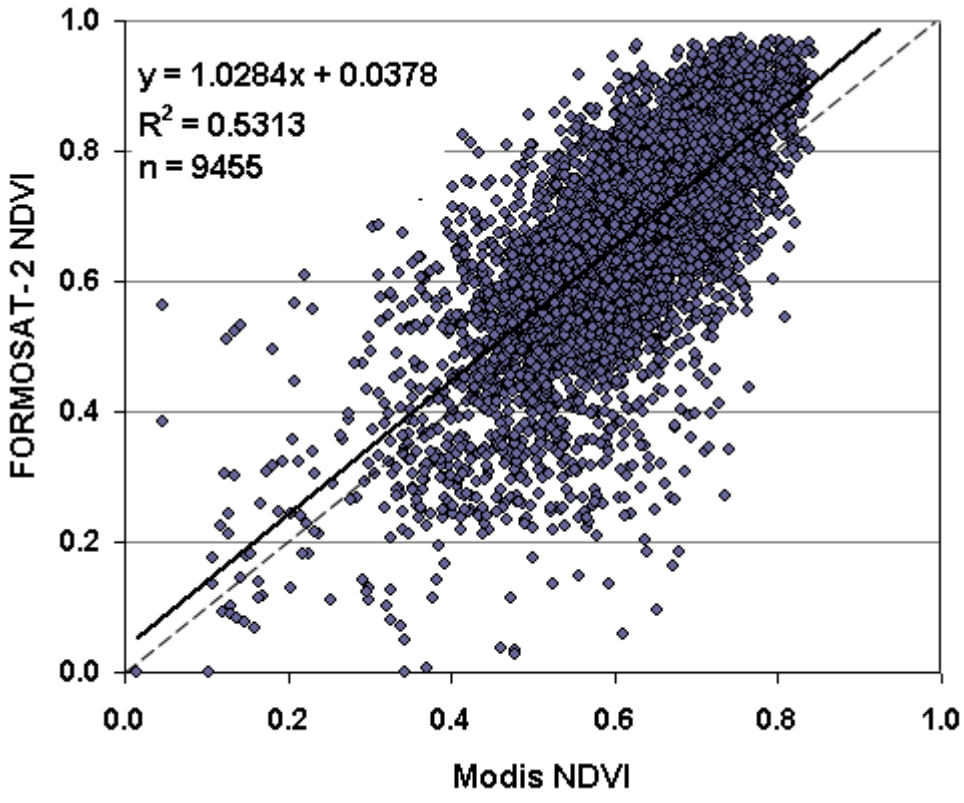

**Figure 3.** Relationship between MODIS NDVI values and corresponding FORMOSAT-2 NDVI values.

### 4.3 Pasture biomass amount and distribution in Bornuur district (August 2009)

Figure 4 depicts the spatial distribution of the estimated pasture amount and distribution in Bornuur district in August 2009, excluding the forest cover. High spatial variability can be observed ranging from 0.6 ton/ha to 1.7 ton/ha. The estimated pasture biomass dynamic range is almost equivalent with that from the FORMOSAT-2 NDVI. Overall, the average pasture amount of Bornuur district as of August 2009 was estimated to be approximately 1.25 ton/ha. This figure corresponded well with other documented statistics (Erdenetuya and Erdenetsetseg, 2008) and proved reasonable.

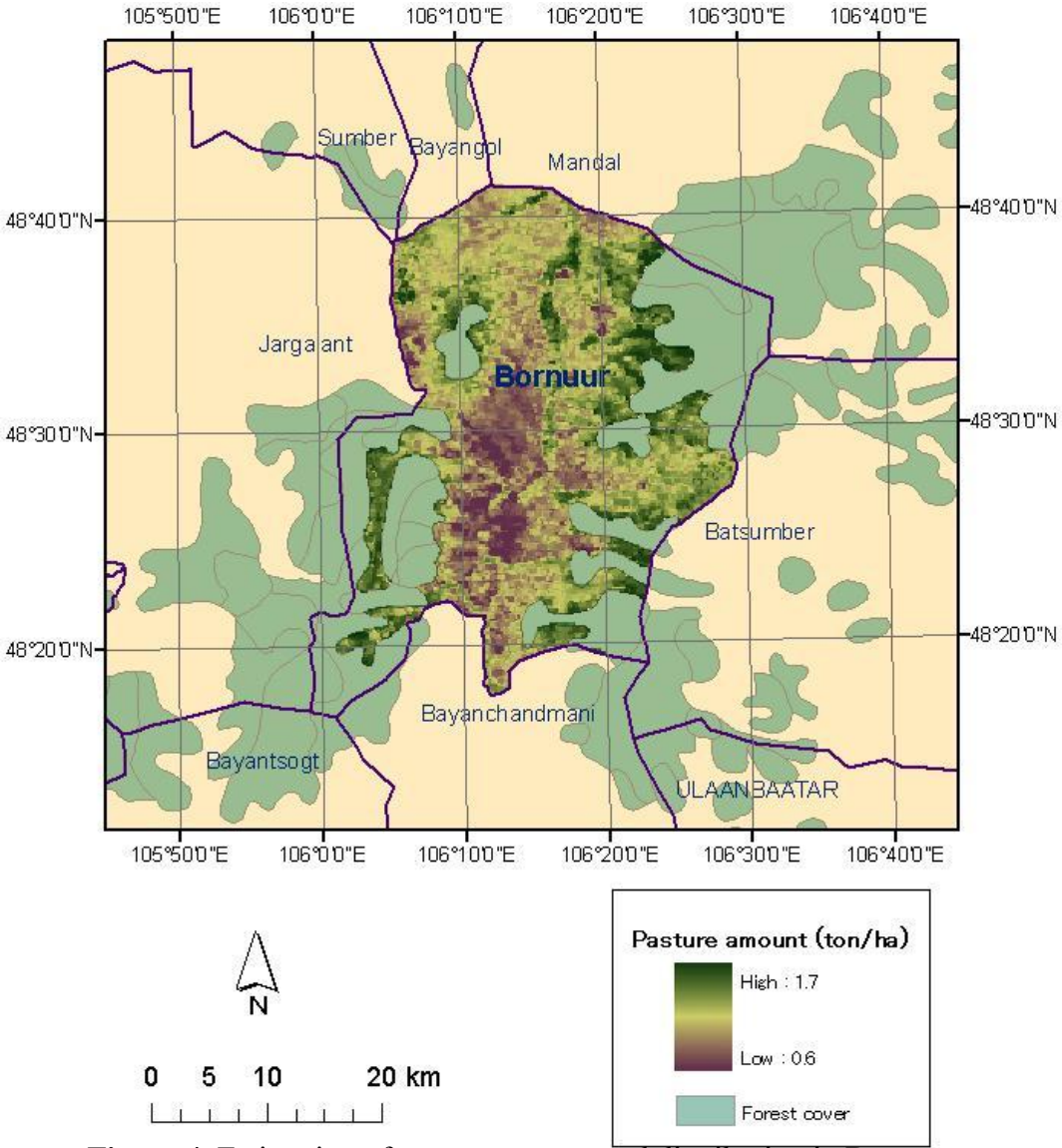


**Figure 4**. Estimation of pasture amount and distribution in Bornuur district in August 2009 using MODIS NDVI.

## 5. CONCLUSIONS

Relationship between MODIS NDVI values and spatial average of corresponding high-resolution satellite NDVI values (FORMOSAT-2 acquired on August 11, 2009) proved satisfactory. This indicated that linking ground measured biomass to high-resolution satellites' spectral information further onto those from frequently observing MODIS data is feasible, at least in the immediate vicinity of our study area in Bornuur district. Based on the relationship previously established between pasture amount and NDVI values, the average pasture amount in Bornuur district in August 2009 was estimated to be approximately 1.25 ton/ha, which agreed well with other existing statistics. The results suggested that it is likely that we can extend the pasture amount estimation procedures using MODIS data in much larger spatial extent, most likely in the forest steppe zone. More work will be needed to confirm the validity of this approach and we are still in the process of collecting additional data to be tested.

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## References

Batbileg, B., 2008. Combining high-resolution satellite data to ground biomass measurements. Proceedings, The 2008 Workshop of AGPAS Project: JIRCAS-MSUA-IMAU Joint Workshop for the Development of Sustainable Agro-Pastoral System in Northeast Asia, pp. 44-45.

Erdenetuya, M. and Erdenetsetseg, B., 2008. Long term satellite data application for pasture land biomass monitoring in Mongolia. In: ISPRS Archives XXXVIII-8/W3 Workshop Proceedings: Impact of Climate Change on Agriculture, p. 355.

Hirano, A., B. Batbileg, K. Shindo, 2008. Cost-effective pasture resources estimation from space. Proceedings, the 29th Asian Conference on Remote Sensing (ACRS), CD-ROM.

NASA/GSFC, 2010. MODIS website, URL: http://modis.gsfc.nasa.gov/about/ (last date accessed: 11 June 2010.)

Tucker, C. J., D. M. Grant, and J. D. Dykstra, 2004. NASA's global orthorectified Landsat data set. Photogrammetric Engineering & Remote Sensing, 70 (3), pp.313-322.