Estimation of Normalized Difference Vegetation Indexes (NDVI) variation by using MODIS satellite data (based on case study from Dornod and Sukhbaatar provinces, Mongolia)

Boldbaatar N.[1], Urtnasan M.[1], Sainbuyan B.[1], Davaadalai B.[1] Narangerel B.[1]

1- INSTITUTE OF GEOGRAPHY AND GEOECOLOGY, MONGOLIAN ACADEMY OF SCIENCES

BACKGROUND

In general, Mongolia has been recognized with relatively well preserved pristine nature. However, some negative changes already being occurred in the environment and natural balances, which leads to land degradation, erosion, reduction of natural resources and loss of ecological balances in some areas. For example, more than one-third of pasture land is already being under high pressure and degradation,due to poor management. Furthermore, nearly 90 percent of the Mongolian territory is considered vulnerable to desertification processes. Thus, currently impacts from human activities are considerably increased on top of the natural and climatic changes.

Remote sensing is widely used in environmental research and there is higher potential for studying pasture land use which is occupies large portion of the Mongolia's territory. Pasture land change depends from various factors, such as vegetation types, geomorphological characteristics, moisture condition and human activity factors. Therefore, studying pasture land degradation by using remote sending data is useful to compare above mentioned different parameters.

RESEARCH OBJECTIVES

Main objective of this study is to determine vegetation coverage changes using satellite data over certain defined time period. The remote sensing data analyses are relatively inexpensive and has more potential to cover large areas with high frequency of measurements. Thus, it is quite suitable in Mongolia, where lacks land observation networks and difficult to conduct routine monitoring of pasture land changes. Within this study, we aimed to conduct vegetation coverage change monitoring, using remote sensing data and determine impacts from climatic factors.

RESEARCH SITE

Eastern Mongolian Steppe region (eastern circle) belongs to the most eastern geomorphological region (E.M.Murzayev, 1952). This region divided into several smaller sub-regions, such as inter-valley, small hilly, steppe hilly,inter-hills depression etc. (Figure: 1)

The Eastern Mongolian Steppe region divided into three bio-geographical regions: Daguur mountainous steppe, Eastern Mongolian tall-grass steppe and Hyangan Mountain.

This region has an inter-continental climatic condition. (F.Shubina). The coldest month is January with average air temperature ranged from -20.2C to -24.4C. In contrary, warmest month is July with average air temperatures ranging from +18C to +22C.

Duration of cold period ranges 145-150 days. The average annual precipitation ranges from 200 to 300 mm. The average wind speed 3.2-4.8 meter/sec. The Strongest wind speed occurs in between April and May. Vegetation growth period is about 5 months, starting from end of April or beginning of May and ends in September or October.

The Eastern Steppe region has different type of vegetation, such as forest, meadow, grassland, sand, water and wetland vegetation.

In the Figure 2 presented dry, rocky and meadow type of steppes. Rocky steppes located in top of the mountains and hills; and also in its slopes. Ordinary and dry steppes located in the hill slopes and river valleys. Meadow steppe located in the mountain slopes and along the River Ulz.

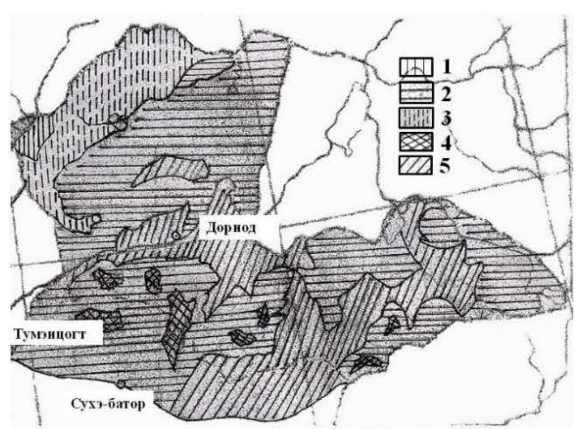


Figure 2. Main vegetation types of the Eastern Mongolian Steppe: 1-forest steppe; 2-5-Steppe (2-Dry steppe; 3-Meadow steppe; 4-Rocky steppe; 5-Ordinary steppe).

2. REFERENCE DATA AND METHODS

2.1 Vegetation cover data / NDVI /

In the analyses were used MODIS/TERRA satellite NDVI images during April to September months of 2000 to 2015 with an accuracy of 1 km, from the NASA's Earth Observing System (EOS).The Normalized Difference Vegetation Index[1] (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains life green vegetation or not.

2.1.2 Precipitation data / TRMM /

NASA and JAXA launched a joint project called the Tropical Rainfall Measuring Mission (TRMM) on 27 November 1997. TRMM aims to measure the intensity and area coverage of rainfall around the tropical and semi-tropical area where two thirds of the world's rainfall happens [50,51]. TRMM can provide accurate precipitation data between latitude 50°N and latitude 50°S at the resolution of 0.25° × 0.25° (approx. 28 km and 28 km), which is high compared to other satellite-based products. There are two TRMM precipitation products commonly used, namely TRMM 3B43 dataset. For this analyses, the TRMM data from April to September months of last 16 years (2000-2015) were used in 0.25 grid or with accuracy of 28 km resolution.

2.1.3 Temperature data / LST /

MODIS/AQUA and TERRA satellite data (MOD/MYD 11A2) from April to September months of 2000-2015 with a spatial resolution of 1 km were used in the analyses.

2.2. Methods

2.2.1. Vegetation cover data / NDVI /

Normalized differences vegetation Indexes (NDVI) of Dornod and Sukhbaatar provinces were calculated, using remote sensing data and GIS (Geographic Information System) software (ArcGIS-10.1 and ENVI-5.3), based on MODIS satellite data from April to September months of last 16 years (2000 to 2015).

$$NDVI = \frac{\rho_{NIR} - \rho_{\mathrm{Red}}}{\rho_{NIR} + \rho_{\mathrm{Red}}}$$ Formula 1

Where, Red - visible light, infrared range 620-670 µm, NIR- infrared (IR) spectrum measured 841-876µm range.

NDVI values were calculated using the above formula and classified its value with the following intervals: $0<NDVI<0.2$, $0.2<NDVI<0.4$, $0.4<NDVI <0.6$, $0.6<NDVI<0.8$ and

[1] - https://en.wikipedia.org/wiki/Normalized_Difference_Vegetation_Index

0.8<NDVI. Such classification helps in evaluation of spatial distribution and determination of migration features.

2.2.2. Standard deviation

Mathematical statistical methods are useful to determine periodic and special changes of any parameters. Therefore, for this study the following formula was used to determine periodic and special changes of NDVI, rainfall and temperature.

$$S = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}}$$ Formula 2

S-standard deviation, x_i- given year (2000-2015), $\bar{x}$ –long term average, N-total number (16), i-years (2000-2015)

3.1. RESEARCH RESULTS

3.1.1 NDVI's long-term trends As results of the study, NDVI values were calculated in last 16 years (2000-2015) in Dornod and Sukhbaatar Provinces (Figure 3).

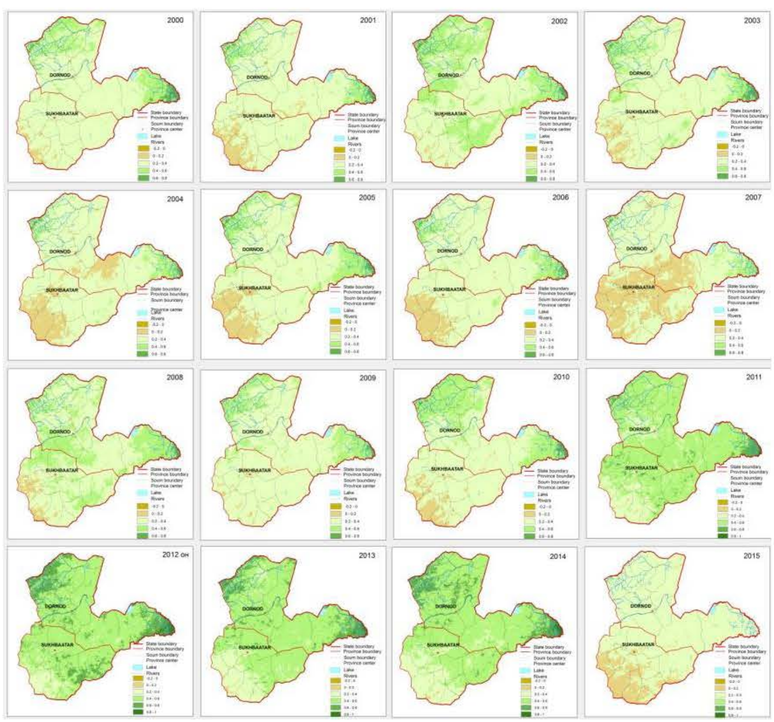


Figure 3. NDVI spatial distribution in Dornod and Sukhbaatar Provinces (2000-2015)

The above image shows that this region has good vegetation cover and varies in different years. During the last 5 years the vegetation coverage (NDVI) has been increased.

3.1.2 Long-term average NDVI

Over the last 16 years, long-term average of the NDVI was calculated in Dornod and Sukhbaatar provinces and presented in Figure 4.

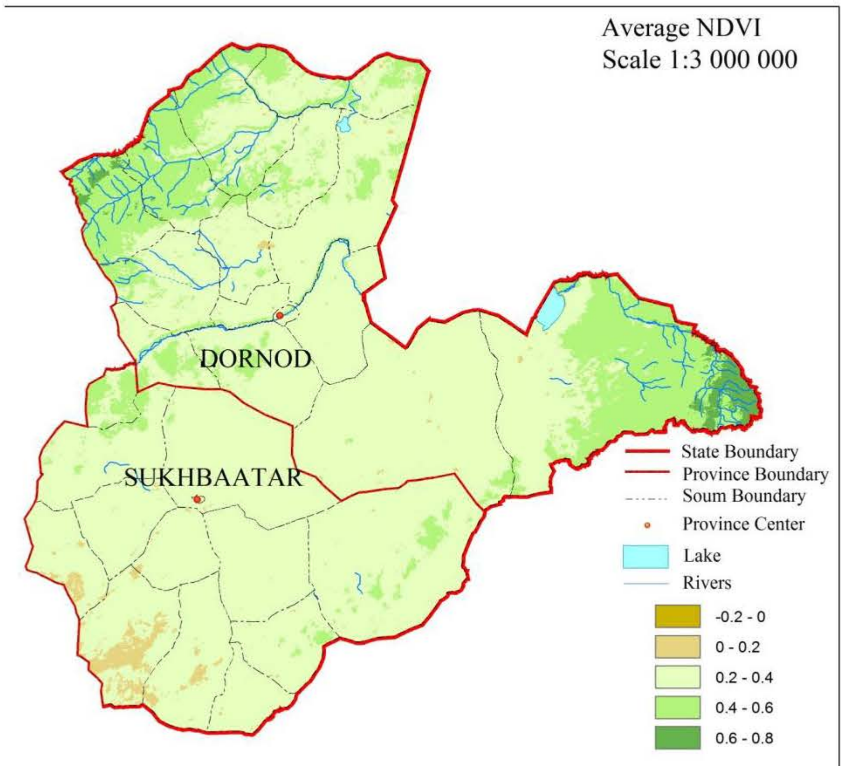
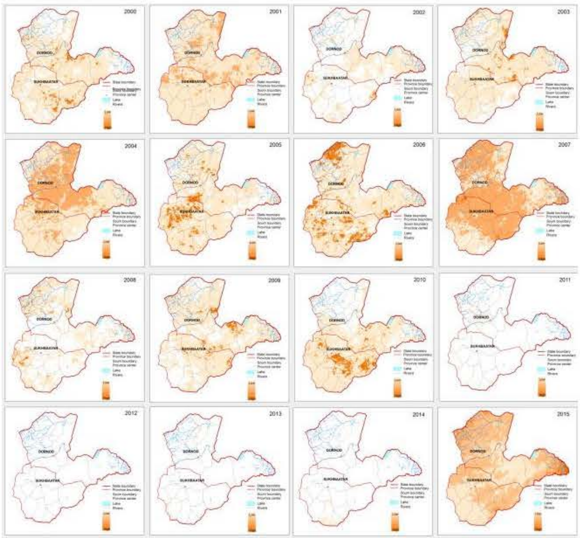


Figure 4. Long-term NDVIaveragein Dornod and Sukhbaatar Provinces (2000-2015)

The average value of the NDVI in warmer months (April to September) of last 16 years can be classified as 0-0.2 (1.9%), 0.2-0.4 (77.2%), 0.4-0.6 (19.6%) and 0.6-0.8 (1.3%). Such classification helps in evaluation of spatial distribution and determination of migration features (Erdenetuya M., 2011).

3.1.3 Long-term vegetation cover change

Standard deviation of NDVI changes from 2000 to 2015 were calculated, only using reduction values of NDVI areas.



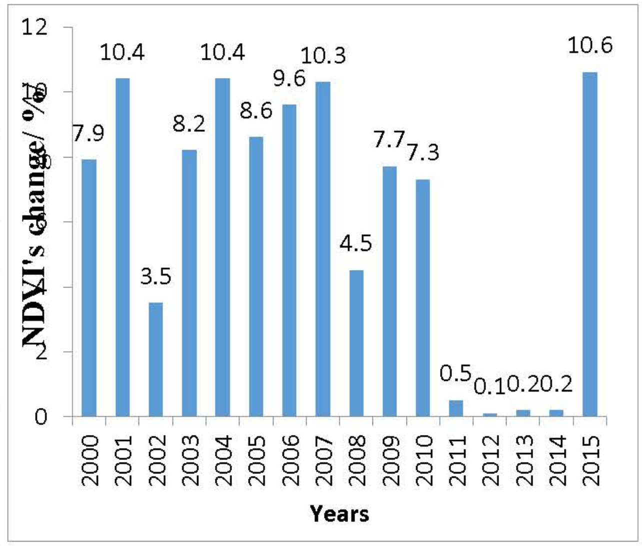


Figure 5. 2000-2015 NDVI-change (reduction) Figure 6. 2000-2015 NDVI-reduction /% /

Figure 5 shows special distribution of NDVI changed (reduced) values during 2000-2015. Annual changes of NDVI increased slightly in all regions in 2011-2014, but it has decreased in other years. This change of NDVI considerably depends from annual weather and climate conditions, in turn, it effects animal husbandry, agriculture and summer condition (vegetation growth).

3.1.4 Vegetation cover's average annual change: Calculated Standard deviation of NDVI difference between 2000-2015 is shown in Figure 6.

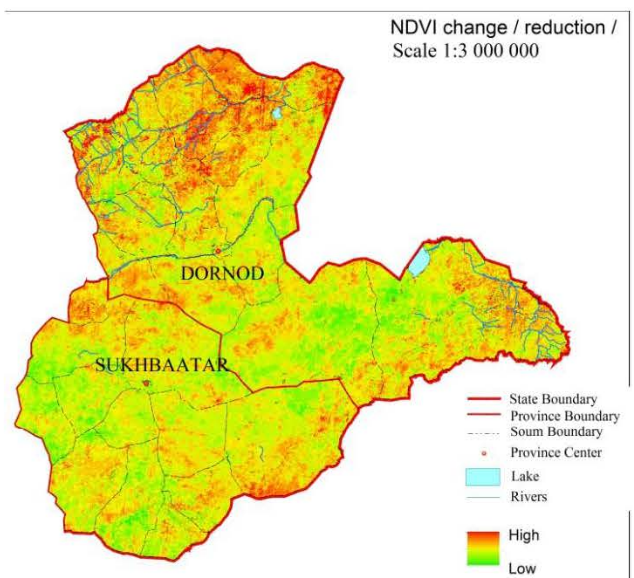


Figure 6. 2000-2015 average NDVI change / reduction /

Vegetation cover change: Long-term changes of NDVI has decreased each year between 2000-2015. If we assume that 16-years NDVI is 100%, than minimum loss occurred in 2012 (0.1%), but maximum occurred in 2015 (10.6%). In some years NDVI value was high, but its area coverage is less. Moderate NDVI areas was gradually decreased. NDVI of this region is good and considerable changes occurred in areas 0.4 <NDVI.

3.2.1 Precipitation trend

Spatial and seasonal distribution of warm season /April-September/ precipitation for the 2000-2015 period was calculated using TRMM data (Figure 7). The results shows that the years of 2000, 2001 and 2006 was drier while other years are more humid.

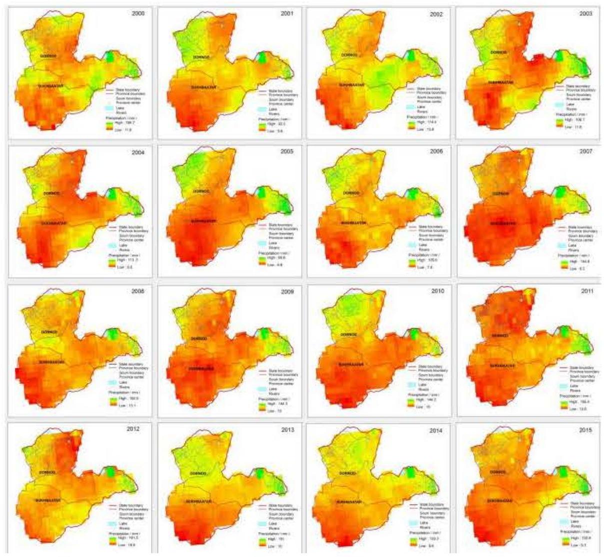


Figure 7. The spatial distribution of precipitation, Sukhbaatar, Dornod Province / 2000-2015 year /

Figure 7 shows that in the relatively low rainfall in 2000, 2001 and 2006 in this area, and high rainfall in other years.

3.2.2 The long term average precipitation

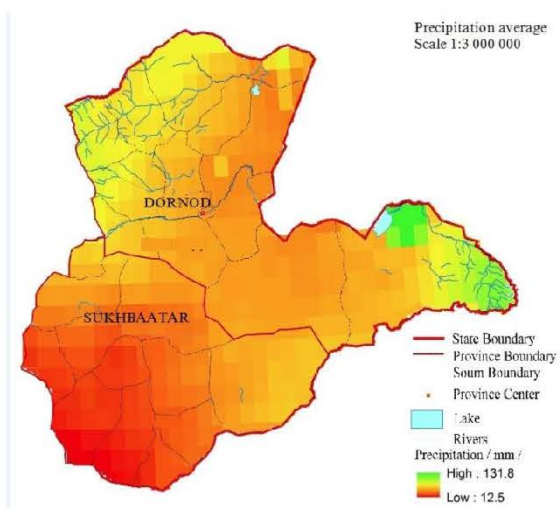


Figure 8. The average precipitation in Sukhbaatar and Dornod provinces / 2000-2015 year /

The long term average precipitation varies from 12.5 mm to 132 mm, higher in the northern and eastern part of the country (Figure 9). Accordingly vegetation cover is relatively good in these places. Precipitation decreases to the south as the steppe converts to gobi.

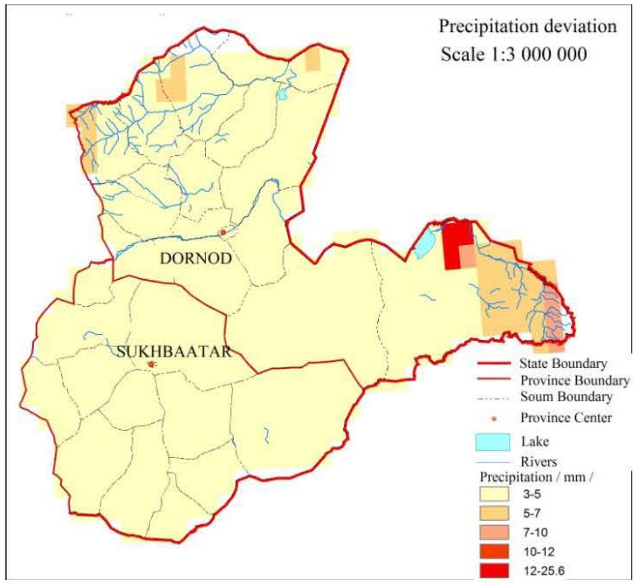


Figure 9. precipitation changes (Sukhbaatar and Dornod Province / 2000-2015 year /

3.2.3 Precipitation changes

Changes in precipitation: The results shows precipitation has decreased by 3-25.6 mm for the 16 years, particularly, 3-5 mm in 92 percent of the region, 5-10 mm -7.5 percent and 10-25 mm - 0.8 percent. This decline of precipitation has affected on the intensity of vegetation cover decline / Figure 6 / and natural disasters.

3.3.1 Land surface temperature trend / LST /

Spatial distribution of land surface temperature derived from MODIS satellite data for 16 years is shown in Figure 10. In years of 2000, 2001, 2002, 2003, 2007, 2014, 2015, the maximum temperature was more than 25°C while in other year did not exceed 25°C. Higher the temperature lover the vegetation cover.

Figure 10. The spatial distribution of temperature, (Sukhbaatar and Dornod province) / 2000-2015 year /

3.3.2 The annual mean land surface temperature

The annual mean temperature of the warm season (April-September) for the 2000-2015 varies 7.1-26.2°C, 15-20°C in forest-steppe and more than 20°C I the steppe and govi region.

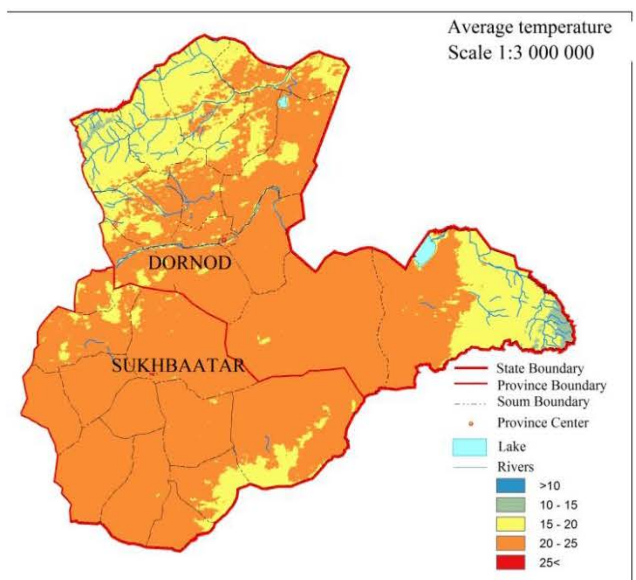


Figure 11. The mean annual surface temperature / 2000-2015 year /

3.3.3 Land surface temperature changes

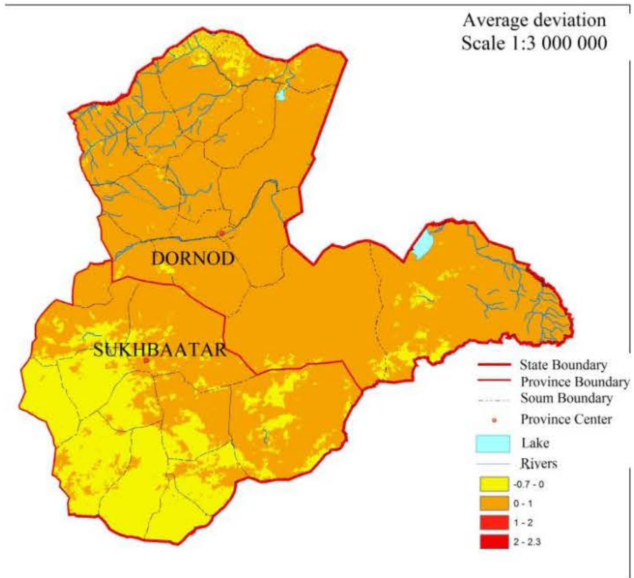


Figure 12. Temperature changes / Sukhbaatar and Dornod province between 2000-2015 year /

An average land surface temperature has increased by 1°C in most of the study area for the last 16 years while it is decreased by 0-0.7°C in 22 percent of the region and increased by 0-2.3°C in rest of the region (78%) per cent Within 16 years. This temperature changes is associated with global warming may also will affect the vegetation cover. Also there is a clear positive relationship between NDVI and precipitation and negative relationship between NDVI and temperature (Table 1).

Table. 1. Temperature relationship between NDVI, precipitation

Average	NDVI	precipitation	temperature
NDVI	1	0.72	-0.69
precipitation	0.72	1	-0.57
temperature	-0.69	-0.57	1

Discussions

Mongolia continental climate is very sensitive to recent global warming. In recent years, This study confirms that climate changes resulted in reduction of vegetation cover by 6.3%, precipitation by 23 mm while land surface temperature has increased by 0.1-2.3 °C in the Eastern region of the country for the last 16 years.

Conclusion

• This vegetation cover / NDVI / study is helpful in agriculture, specially for pastoral as well as livestock farming for pasture managers for sustainable use of pasture such as fattening of animals in summer time and hay preparation and reservation in fall.

• According the changes of NDVI during 2000-2015, NDVI value was decreasing from year to year. If take the changes between 2000-2015 equal to 100 percent, then the lowest decrease of 0.1% is observed in 2012 and higherst of 10.6% in 2015. In some years NDVI is high but the area covering is quite small.

• The precipitation has decreased by 3-25.6 mm for the 16 years, particularly, 3-5 mm in 92 percent of the region, 5-10 mm -7.5 percent and 10-25 mm - 0.8 percent. This decline of precipitation has certain impact on the intensity of vegetation cover decrease /Figure 6/ and natural disasters.

• An average land surface temperature has increased by 1°C in most of the study area for the last 16 years while it is decreased by 0-0.7°C in 22 percent of the region and increased by 0-2.3°C in rest of the region (78%) per cent Within 16 years.

Thanks

Great thanks goes to team of the division of Cartography and Geographic Information System, Institute of Geography and Geoecology, Mongolian Academy of Sciences for their contribution and support to conduct this study.

References

1. http://disc.sci.gsfc.nasa.gov/
2. http://www.mdpi.com/
3. https://lpdaac.usgs.gov/
4. Mohd Rizaludin Mahmud[1,*], Shinya Numata[1], Hiroshi Matsuyama[1],Tetsuro Hosaka[1]and Mazlan Hashim[2] , 2015.Assessment of Effective Seasonal Downscaling of TRMM Precipitation Data in Peninsular Malaysia
5. Fengrui Chen [1,2,*] and Xi Li [3,4,*] , 2015.Evaluation of IMERG and TRMM 3B43 Monthly Precipitation Products over Mainland China
6. Ya Liu[1,2], Yan Li[1,2], Shuangcheng Li[1,2,*] and Safa Motesharrei[3,4,5] , 2015.Spatial and Temporal Patterns of Global NDVI Trends:Correlations with Climate and Human Factors
7. Yuli Shi[1,2,*,] Lei Song[1], Zhen Xia[1], Yurong Lin[1], Ranga B. Myneni[3], Sungho Choi[3], Lin Wang[1], Xiliang Ni[2], Cailian Lao[3,4] and Fengkai Yang[1], 2015.Mapping Annual Precipitation across Mainland China in the Period 2001–2010 from TRMM3B43 Product Using Spatial Downscaling Approach
8. Zhong Liu, 2011. TRMM and Other Global Precipitation Products and Data Services at NASA GES DISC
9. Zachary Christman[1,*,] John Rogan [2,] J. Ronald Eastman [2,3] and B. L. Turner II [4], 2016.Distinguishing Land Change from Natural Variability and Uncertainty in Central Mexico with MODIS EVI, TRMM Precipitation, and MODIS LST Data