

FREQUENCY ANALYSIS OF MODIS NDVI TIME SERIES FOR DETERMINING HOTSPOT OF LAND DEGRADATION IN MONGOLIA

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ABSTRACT:

This study examines MODIS NDVI satellite imagery time series can be used to determine hotspot of land degradation area in whole Mongolia. The trend statistical analysis of Mann-Kendall was applied to a 16-year MODIS NDVI satellite imagery record, based on 16-day composited temporal data (from May to September) for growing seasons and from 2000 to 2016. We performed to frequency analysis that resulting NDVI residual trend pattern would enable successful determined of negative and positive changes in photo synthetically health vegetation. Our result showed that negative and positive values and generated a map of significant trends. Also, we examined long-term of meteorological parameters for the same period. The result showed positive and negative NDVI trends concurred with land cover types change representing an improve or a degrade in vegetation, respectively. Also, integrated the climate parameters which were precipitation and air temperature changes in the same time period seem to have had an affecting on huge NDVI trend area. The time series trend analysis approach applied successfully determined hotspot of an improvement and a degraded area due to land degradation and desertification.

1. INTRODUCTION

Desertification is one of the most serious environmental challenges which after affecting the most basic livelihood conditions and resources of people around the world. According to the United Nations highlighted to the first international conference on desertification in Nairobi, Kenya in 1977 (UN Secretariat 1977), land degradation in arid, semi-arid, and dry sub-humid areas further indicated to dry lands might result from various factors, including climatic variations and human activities (UNCCD, 1994; UNCCD 2012). Also, researchers found that the land degradation is a most important issue of societal in order to it impacts on human populations and environment quality (Vitousek et al. 1997). Moreover, the land degradation is frequently referred to as desertification might be the most important environmental issue. Several researchers were mainly described to that point (Darkoh, 1998; Dregne, 1996; Reynolds, 2001). Specially, Batjargal (1997) recommended that about 35-50 tons of soil have been lost from hectare of cultivated land due to wind erosion alone in over the past 30 years.

Additionally, the study is clear to note that the carrying capacity of pasture land is profound frequently exceeded in the areas receiving the greatest grazing pressure in order to that impact to the degradation for the composition of plant species and soil denudation (Batjargal, 1997). Consequently, an adverse effect of anthropogenic activities such as overgrazing have accelerated, causing vegetation degradation to so that it become the dominant type of rangeland degradation in semi and semi-arid zone. A few studies have been demonstrated that issues (Adyasuren 1998; Batjargal 1999; Fujita et al. 2009).

In additional, some case studies, more strongly highlighted which the rangeland management and monitoring using field surveys, particularly over vast and remote huge areas, may be problematic since these are expensive, manpower-demanding, application

and time-consuming processes. Therefore, space platform remote sensing, with it could be cover by large surface area and time frequent, routine observation has been used for broad relate to vegetation applications in environmental monitoring in semi-arid region. For instance, such aspects include: biomass estimation (Jin et al. 2014); NDVI trends from AVHRR and vegetation SPOT (Yin et al. 2012); vegetation indices for the identification of Archaeological Crop marks (Agapiou et al. 2012); Long term vegetation dynamic and response to climatic change (Bao et al. 2014); spatial and temporal variability of vegetation cover (Vandendorj et al. 2015); comparative evaluation of the vegetation dryness index, the temperature vegetation dryness index and the improved for the detect water stress in the semi-arid regions (Rahimzadeh et al. 2012); the spatial occurrences of droughts, detected by remotely sensed drought-indices over the desert-steppe and desert geo-botanical zones (Bayarjargal et al. 2006); regional higher resolution based drought monitoring (Ghaleb et al. 2014); Remote sensing of Agro-droughts (Gao et al. 2008); satellite based analysis of recent trends in the ecohydrology of semi-arid region (Gokmen et al. 2013). And another main effect of land degradation is conducted drought process that might be influence and devastate large regions, reduce livestock production, cause economic damage, accelerate desertification in association with destructive human activities. Therefore, in order to it has applied remote sensing-based indices such including normalized difference water index (NDWI), vegetation health index (VHI), temperature condition index (TCI), vegetation condition index (VCI) and meteorological index (PED) in whole territory of Mongolia (Chang et al. 2017). However, as mentioned possibility indices were could not have identified specific narrow area.

There have been several studies representing a generally sufficient agreement on different sensors between the normalized difference vegetation index (NDVI) long term data from

AVHRR, Spot and MODIS. The grazing and land degradation changes of over Mongolia, based on statistically analysis according to (Erdenetuya, 2004; Eckert et al. 2015). Moreover, some researchers investigated to identifying the most stable and unstable regions of vegetation cover and temporal dynamics compare with precipitation in Mongolia. Some scholars found that highest coefficient of variation CV vegetation cover occurred frequently in the steppe and desert steppe about high CV more than 30 % has increased in mid-summer season. (Vandandorj et al. 2015). However, could have not studied pressure of animal husbandry to the land degradation.

In this study, the authors are mapping to hotspot area of land degradation in over Mongolia. It has been applied the frequency analysis and Mann-Kendal statistical methods. In addition, an advantage of the study was taken issues of the social economy, climate variables were compared with and remote sensing imagery in order to estimate the land degradation. Moreover, the purpose of an evaluation to the trend of land degradation and identifying hotspot distribution based on geospatial statistic techniques.

2. STUDY AREA

The study area's land cover types are high mountain taiga, forest, steppe, desert, semi desert, barren land and others types in Mongolia (Khudulmur et al., 2014). Mongolia is located in the central part of Asia which latitude between (41⁰ and 52⁰ N and longitude between 87⁰ and 120⁰ E). and a total territory is 1,564,116 km². About 7% of the total area covers with forest and 73% of it dominates by grassland (CIA, 2017).

In contrast, the northern part of area is covered by higher mountains with forested and middle part is a huge grazing land which is steppe area, whereas the southern part covered by the Gobi and desert and semi desert zone with lower elevation and drier climate (Batima et al., 2000). Furthermore, Mongolia has a continental climate and it is characterized by cold, dry and harsh (snowy) winter and warm, limited rainy in summer.

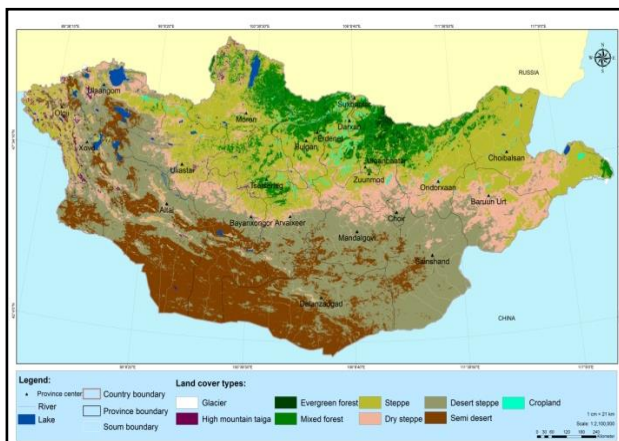


Figure 1. Land cover map of Mongolia and that contains major land cover types such including high mountain, steppe and desert area derived from MODIS/Aqua 250m image.

Some researcher founded that the temperatures range were from approximately -18⁰C in winter to around 16⁰C in summer (Dagvadorj et al. 1996). Moreover, the amount of annual precipitation is relatively low and it ranges 150–250 mm in the steppe regions, more than 400 mm in the mountain areas. Therefore, several researchers were highlighted that 85–90% of the annual precipitation could have happened in the summer season (Dorjsuren et al., 2016).

3. MATERIALS AND METHODS

3.1. Satellite data

The normalized difference vegetation index (NDVI) is could use a proxy for terrestrial vegetation efficiency in studies of vegetation trends at regional scales in order to significantly related with ecosystem (Forkel et al. 2013). Terra/MODIS NDVI 250-meter spatial resolution and 16-days composite imagery acquired in from the early of 2000 to 2016⁷ totally 17 years data. It contains the enhanced vegetation index (EVI) and the normalized difference vegetation index (NDVI) and it has contained the most reliable pixel values (Huete et al. 1999). These some of data from 2000-2008 years were download from the NASA's Earth Observing System Data and Information System (EOSDIS) open source site <https://search.earthdata.nasa.gov> and another part of data from 2009-2017 years were obtained from Data Catalog Services of the National Remote Sensing Center of Mongolia (NRSC) site www.icc.mn. We collected 11 Julian days are including such as 129, 145, 161, 177, 193, 209, 225, 241, 257, 273, and 289 that all cover the vegetation phenology stage from May to October.

3.2. Meteorological and Livestock data

The meteorological data in Mongolia are situated at 70 the international weather stations in meteorological observation network of World Meteorological Organization some research highlighted that information (Eckert et al. 2015). Currently there are working 130 regional meteorological stations, 186 meteorological posts and 3 upper-air stations in observation network under the National Agency for Meteorology, Hydrology and Environment Monitoring of Mongolia (NAMHEM) Therefore, stabile several parameter were observed variables in all meteorological stations such as includes (Air temperature, surface soil temperature, atmospheric pressure, humidity, velocity and direction of wind, precipitation /amount and intensity/, cloud amount and type, visibility, weather /present and past/, snow depth and density (Battur, 2010) In addition, we were used the precipitation and air temperature of 113 meteorological station data from 2000 to 2016 obtained from the division of database and archive of NAMHEM. The number of livestock data derived from Mongolia Statistical Information Service, site (www.1212.mn) by totally 17 years data collected which between from 2000 to 2016.

3.3. Method

In this study, we were used that the one of statistical techniques implemented in the statistical analysis which is the nonparametric Mann-Kendall test for trend (Mann, 1945; Kendall, 1975). Moreover, some researchers noted that the Mann-Kendall test could be viewed as a nonparametric test has considered zero slope value of the linear regression of time-ordered data versus time, according to as highlighted by Hollander and Wolf (1973, p.201). Also, another researcher founded that the yearly aggregation of time series for trend analysis reduced by the temporal resolution and time series length. Therefore, the time series scale is analytical in identifying the significance of the trend in the non-parametrical statistical test (Forkel et al. 2013; Huang et al. 2016).

The land degradation map produced by the Image processing and Geographic information system. All data pre-processing and analysis were used by ERDAS imagine, TerrSET IDRISI the and ArcMAP. So that we aimed to identifying the Hotspot of land degradation over Mongolia by improved, degraded and non-changed area. In generally, we used biophysics and social economical parameters. Figure 2 represents a workflow of pre-processing and draw map of this study area.

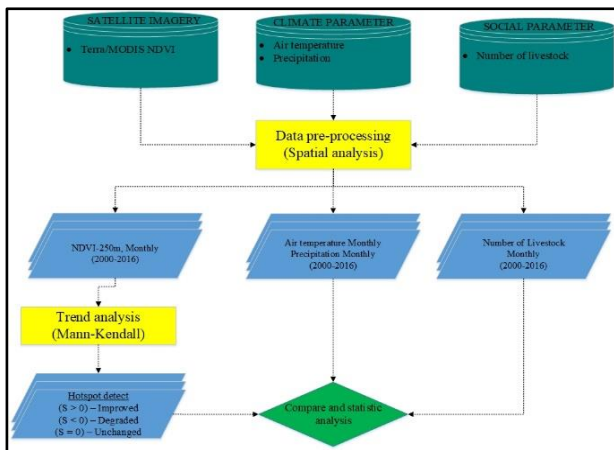


Figure 2. Flowchart of hotspot of land degradation for study area

In workflow processing method, main three different groups were used into several parameters includes such as Terra/MODIS Imagery, Air temperature, Precipitation and number of Livestock etc.

In addition, the spatial analysis was used the image pre-processing and ancillary data analysis. Therefore, pre-processing is used image composite which from per 16 days NDVI to per monthly NDVI, daily meteorological station data convert to monthly data and annual number of livestock. Whereas, the statistical analysis performed the trend and frequency method. Thus, we have been implemented using the normalized difference vegetation index (NDVI) (Tucker 1979). NDVI is calculated by following Equation (1).

$$NDVI = \frac{\rho_{NIR} - \rho_R}{\rho_{NIR} + \rho_R} \quad (1)$$

Where, ρ are reflectance values in the particular spectral channels. NDVI is built on the difference between the maximum absorption of radiation in the red (R) spectral range (as a result of chlorophyll pigments) and the largest reflection of radiation wave in the near infrared (NIR) range (as a result of leaf cellular texture). The calculation of frequency analysis is computed by following Equation (2).

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n sgn(x_j - x_k) \quad (2)$$

$$sgn(x_j - x_k) = \begin{cases} 1 & \text{if } x_j - x_k > 0 \\ 0 & \text{if } x_j - x_k = 0 \\ -1 & \text{if } x_j - x_k < 0 \end{cases}$$

Where, x_1, x_2, \dots, x_n is represent n data points
 x_j is represent the data point
 j is at time
 S is the Mann-Kendall statistic

This the test statistic, S is equal to the total number of positive differences minus the number of negative differences for each time step.

In order to compare between NDVI changes, air temperature, precipitation and number of livestock the correlation coefficient (r) is calculated the following Equation (3):

$$r_{xy} = \frac{\sum_{i=1}^n [(x_i - \bar{x})(y_i - \bar{y})]}{\sqrt{\sum_{i=1}^n [(x_i - \bar{x})^2 (y_i - \bar{y})^2]}} \quad (3)$$

where, r_{xy} is the correlation coefficient.

x_i and y_i are the variables of NDVI changes, air temperature, precipitation and number of livestock.

\bar{x} and \bar{y} are the mean value of the variables of NDVI changes, air temperature, precipitation and number of livestock.

n is the number of variables in two parameters.

In addition, the linear correlation (r) in degraded NDVI and number of livestock was explored at annual value, as well as statistical highly significance level (p) have chosen at the (<0.001) in this study.

4. RESULTS AND DISCUSSION

The global studies have suggested that the world's semi-arid have been showing a rapidly increase in vegetation activity, the human pressure and as a consequence of warm climate process might impact to land degradation operation (Vicente et al. 2015). Figure 3 shows that the statistical trend of the hotspot of degraded land and Improved land area were demonstrated over in Mongolia from 2000 to 2016.

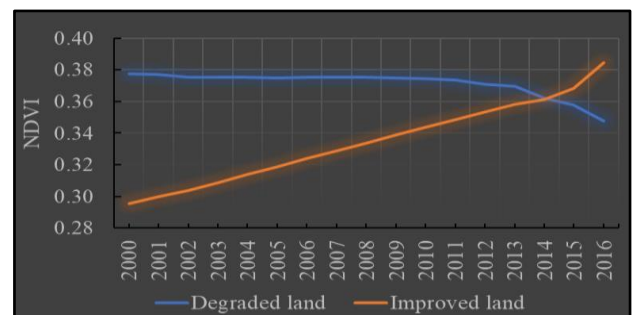


Figure 3. The statistical trend of the hotspot of degraded land and improved land area in study site, 2000-2016

In Figure 3, a trend of trend of the hotspot of degraded land and improved land area have been showing differently phenomena in this study area. In 2000-2010 the degraded land was gradually decreased by from an about 0.380 value to 0.371 value of NDVI, and after that this curve exponentially climbed to an approximate 0.348 of value of NDVI in 2016. On the other hand, the improved land area was dramatically increased from 2000 to 2016 in the study area. Figure 4 represents the relationship between a number of livestock and hotspot of degraded land.

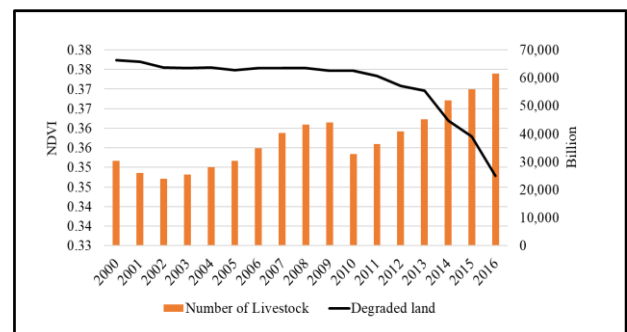


Figure 4. The relationship between the number of livestock and hotspot of degraded land, 2000-2016

Particularly, the attitude of the number of livestock was gradually grew from 2000 to 2009, whereas 6 years of number of livestock sharply increased by around 61 billions. In generally, these parameters between livestock and degraded land were well related with each other in the whole study period. The correlation coefficient (r) of the number of livestock and hotspot of degraded land were negative 0.97 with a highly significance level of $p < 0.001$. For example, main assumption was the number of livestock might have pressured to land degradation. Also, another main a comparison analysis of the degraded land, Air temperature and precipitation are illustrated in Figure 5a, b. So that we were compare between the degraded land and climate parameter by each one, a value of warm season combined from May to September for the year 2000 to 2016 in both parameters.

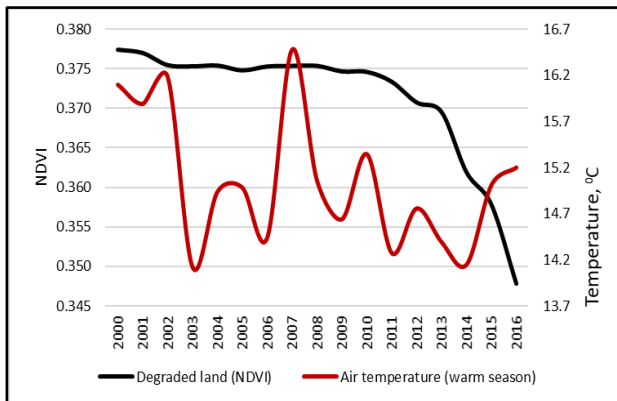


Figure 5a. The temporal variation between degraded land and air temperature.

In figure 5a, the graphic illustrated that air temperature staidly decreased, however 2000, 2001, 2007 and 2016 in highlighted period extremely hot, end of period slightly increasing by about 15.2 Celsius. On the other hand, the degraded land was exponentially decreased.

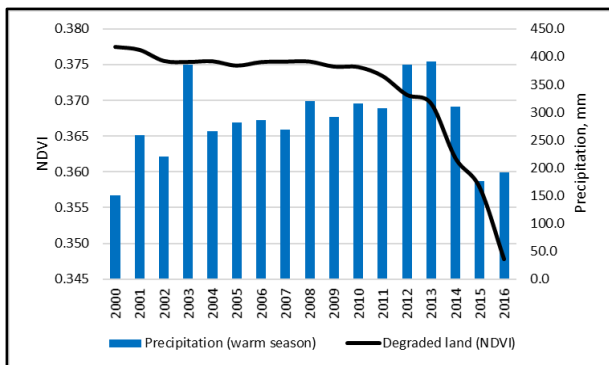


Figure 5b. The temporal variation between degraded land and precipitation.

In figure 5b, the graphic showed that the precipitation staidly increased up to in 2013 and rapidly decreased about 200 mm of annual rainfalls in 2016. For example, some researchers founded that in 2000, 2001, 2007, 2009 were the dries years which is suggesting lower rainfall and higher temperature, in order to became drought occurred in the time 2001 and 2007 (Munkhzul et al. 2016). Therefore, these were as well as related between precipitation and degraded land, particularly last 3 years in this study area.

The final result maps have been representing in figure 6 which is the hotspot area by three categories includes such as degraded area, improved area and unchanged area over period in 17 years.

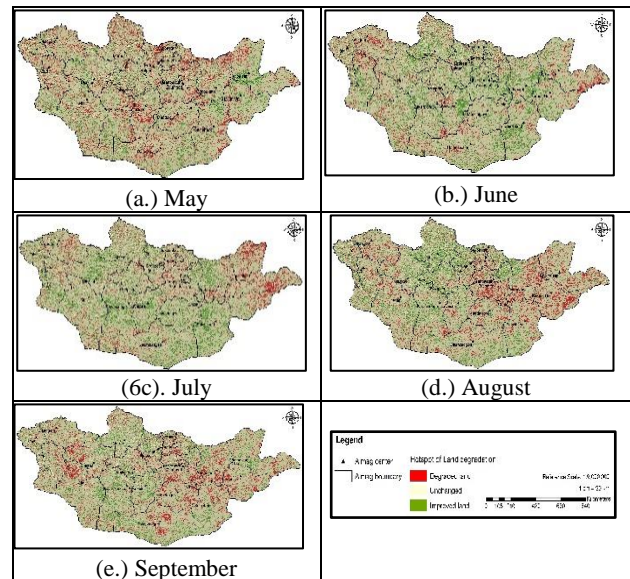


Figure 6. The hotspot of degraded land area of Mongolia

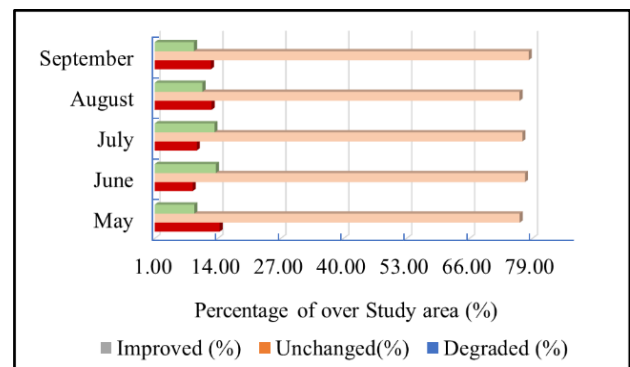


Figure 7. The percentage of hotspot area in over Mongolia from 2000 to 2016 by monthly growing season.

In figure 7, it is interesting to note that even among different kind of the hotspot area normally considered alike such as a degraded area and improved area. But our focus is considered degraded area in order to highly reflect months were May, August and September which are demonstrating in figure 6a, 6d and 6e, by an approximate 14% of area. It is situated mainly western, middle, south and eastern half of area are degraded in over period. Moreover, in figure 6b and 6c were about 13% of area degraded.

Therefore, it is demonstrated by June and July which situated in eastern border to Dornod aimag, and over time within 17 years. On the other hand, improved area was around 12-13% of study area, and the unchanged area was quite different pattern but not much changed about nearly 79 % in per months, and within 17 years.

5. CONCLUSION

This study performs that our proposed approach was used to integrate with the hotspot of land degradation area and social economy both the temporal variation of parameters which analyzed with the number of livestock, air temperature and precipitation by during 17 years from 2000 to 2016.

We were used that the one of statistical techniques implemented in the statistical analysis which is the nonparametric Mann-Kendall test. The hotspot of land degradation map of study area was classified into three categories and is based on frequency

trend statistics adequately to assess a respective class: degraded area, unchanged area and improved area. An approximately (14 %) of the study area was degraded, and about (13%) of the area improved and around (78%) of area was unchanged in study area over 17 years.

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