

VARIATIONS OF VEGETATION NET PRIMARY PRODUCTIVITY AND ITS RESPONSES TO CLIMATE CHANGE FROM 1982 TO 2015 IN MONGOLIA

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ABSTRACT:

Climate warming in Mongolia is relatively high, with extreme dry climate, and low precipitation, the input of green vegetation on the ecosystem functioning is relatively high. The impacts of climate change are critically affected to desertification, biodiversity loses, decreases of water sources, land degradation of rangeland in Mongolia. In order to better adapt to such changing climate, it is important to understand the long terms vegetation dynamics and its relation with precipitation. In this study, the third-generation GIMMS NDVI data of NOAA satellites and CASA model with metrological data have been used to estimate NPP between 1982 and 2015 throughout Mongolia. Results show that during 34 years mean NPP seems to have decreased greatly from semi-arid in the North to desert in the South across natural zone in Mongolia. The average NPP value was averaged at 166.1 g C/m² and ranged between 19 and 724.85 g C/m² for the terrain land. 60% of total NPP was relating to annual precipitation about R²=0.78 (p=0.000). Total amount of NPP between 1982 and 2015 was estimated to be 0.32 P g C/year and 0.29 P g C/year in 1982 and 2015, respectively, with an average amount of NPP was 0.32 P g (1Pg=10¹⁵g) for 34 years. These results indicate that during most of vegetation growing season, NPP decreased by 0.03 P g C/year. Field measurement data of 2007, 2009, 2014 and 2015 were used for correlation with the NPP estimation. As a result, R²=0.742 (p<0.001) in 2007 for forest steppe, R²=0.74 (p<0.001) in 2009 for meadow steppe and grassy steppe, R²=0.73 (p<0.001) in 2014 for meadow steppe, R²=0.715 (p<0.001) in 2015 for a desert steppe, respectively. The results obtained in this study contributes to understanding productivity of pasturelands of semi-arid ecosystems of Mongolia and Central Asia. By providing insights on the relationship between pasture productivity and climate variables such as precipitation and temperature, this study could be useful for national and regional scale climate change adaptation strategies.

1. INTRODUCTION

Rangeland accounts for almost half of Earth's continental surface, and it stores and sequestrates significant amount of carbon in the soil. With this significant characteristic, rangeland ecosystem functions play critical role to global carbon balance. Carbon, the most widely distributed GHG type, is stored in plants and soil; on the other hand, unsustainable use of forest and rangeland turning into urban lands, excessive use of forest resources and degradation of rangeland serve as catalyst to release carbon to earth atmosphere. Annual plant productivity is determined by the surrounding climate conditions and characterized by temperature, humidity and light supplies (Natsagdorj, 2012).

Vegetation Net Primary Productivity (NPP) refers to formation/accumulation of organic matters formed by photosynthesis during a given time unit for a given unit of area, shown as (g C/m²/year), and expressed in values as gross primary productivity formed by photosynthesis minus the rate of energy loss to metabolism and maintenance. In other words, it's the value showing difference between the total consumption of photosynthetic light for inhalation or, to state differently, the difference between autotrophic respiration. Vegetation NPP is determined by terrestrial carbon turnover and carbon balance processes and serves as the main clean source for food for human being (Yu, 2009). Driven by climate change, annual vegetation productivity has deteriorated during past two

decades, among all, productivity in central region and western part of eastern region have shown 5- 13% decrease as opposed to 29-year average of 1961-1990 (Natsagdorj, 2009).

Carbon movement/changes in the rangeland ecosystem is determined by precipitation, in particular, small amount of precipitation in Mongolia's semi-arid region makes significant impact on rangeland ecosystem carbon moves.

Rangeland accounts for about 80% of Mongolia's total landmass. Most importantly, rangeland must be used sustainably consistent with its carrying capacity through rotations. Subsequent years of rangeland use without rotation results in 30- 40% of decrease in plant forage (ADB. Making Grasslands Sustainable in Mongolia, 2014). Following plant scarcity, its capacity for carbon absorption also reduce whilst contributing to temperature rise.

On the other hand, pastureland provides wide variety of ecosystem regulatory services and functions, including regulation of climate through serving as source for carbon and carbon sequestration, regulation of dust storm and soil erosion and preserving rangeland biological diversity (ADB. Making Grasslands Sustainable in Mongolia, 2014).

In the event that Mongolia reduces its number of livestock fit to existing rangeland carrying capacity, carbon storage in the pasture soil will increase. Herders need to obtain tools and methodologies for carbon sequestration and capture calculations and get certified for carbon emission reduction, which can be

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stored in the mutual fund of the pasture user groups, for credits when they are in need of cash; this will prevent herders from selling their animals at cheaper prices to meet their immediate cash needs (ADB. Making Grasslands Sustainable in Mongolia, 2014). Other research findings cited that plant growth period in Mongolia expanded by about two weeks (Bolortsetseg, 2002) and this caused carbon content in the air reduce early in spring till late autumn (Natsagdorj, 2012). With overall impact of climate change, warming trend has been clearly been observed in Mongolian climate. Driven by increase in GHS emission in the earth's atmosphere, annual average temperature on the ground rose by 2.25°C in the past 79-year period ($p < 0.05$ confidence interval) (Gomboluudiv, 2017). If this value is compared against the global temperature rise since 1880, warming process has taken place several times fast, according to above scientists. The number of previous studies on carbon absorption capacity of Mongolia's rangeland were found relatively low. A study "Linking herders to carbon market" made an attempt to identify the amount of carbon reduction by improving rangeland management in Mongolia. This study was made using Tier 1 level tool, adopted by Intergovernmental Panel on Climate Change finding that improved rangeland management in Mongolia would potentially reduce carbon emissions at higher amount, namely 29 million-ton CO₂ equivalent, per year. In the period of 1970-1990, a joint Mongolia- Russia expedition carried out a research aimed at determining the rangeland plant on-ground and sub-soil phytomass at the research points representing Mongolian natural zones, coupled with plant photosynthetic study (Davaajamts, 1988) and (Davaajamts, 2014). Research on plant carbon storage and NPP using time series (years) were found rare, almost not existent. Calculation of NPP in Mongolia plays vital role for determining the seasonal vegetation changes, roles of rangeland in the carbon turnover in the dry land ecosystems and ensuring proper and sustainable use of limited pasture resources. For this research, scientists applied Carnegie-Ames-Stanford Approach (CASA) model using 34-year NDVI and climate data to identify NPP and analyzed its relevance to climate change.

In this study we used CASA model to simulate changes in NPP patterns as well as their response to climate factors in Mongolia during 1982–2015. The main objectives of this study are (1) to estimate the spatial patterns in terrestrial NPP in Mongolia, (2) to better understand mechanisms influencing spatial and temporal patterns of terrestrial NPP, (3) to identify climate responses on vegetation productivity.

2. MATERIAL AND METHODS

2.1 The CASA model

Of wide variety of methods for calculating the vegetation NPP, CASA (Carnegie-Ames-Stanford Approach) (Potter et al. 1993; Field et al. 1995), GLO-PEM (Prince, Goward. 1995), and C-Fix (Veroustraete et al. 1994) were found the most common LUE models among all. CASA model that we use predominantly in the research, is grounded on photosynthetic light use efficiency (light use efficiency-LUE) theory as referenced by (Potter et al. 2017) and (Filed et al. 1995), initiated by Monteith, 1972 and the NPP is a product of Absorbed Photosynthetically Active Radiation and Light Use Efficiency (LUE). CASA model, which we applied for the research, is considered a simple representative of light use energy models, and it calculates FPAR model parameters using model input parameters, satellite data (NDVI, LSWI and so on). It is widely used globally and regionally for vegetation NPP modelling studies. CASA model is based on GIS (Geographical

information system) and remote sensing, uses vegetation NDVI, total solar radiation, weather data (precipitation, temperature) for calculation of vegetation NPP. Many scientists reckon this model as the optimal way of calculating NPP of a specific area or the global world.

This model consists of two sub-models, including the amount active light absorbed in plants and light use efficiency.

$$NPP(x, t) = APAR(x, t) \times \varepsilon(x, t) \quad (1)$$

Where, APAR(x,t) (Absorbed Photosynthetically Active Radiation) means the fraction of the incoming solar radiation per unit of area absorbed by plants, or the value of active radiation photosynthetically absorbed by plant (Measuring unit: g C/MJ), and $\varepsilon_{(x,t)}$ means photosynthetic coefficient of plant per unit area in the per unit of time.

$$APAR(x, t) = SOL(x, t) \times FPAR(x, t) \times 0.5 \quad (2)$$

Where, SOL_(x,t) means the value of interpolation between total monthly solar radiation received by meteorological stations while FPAR_(x,t) shows amount of active light absorption, as described and proposed by Los S.O (Los, 1998) and (Bao et al. 2016). 0.5 refers to amount that plants can absorb the active solar radiation.

Many scientists think that 0.38-0.71μm wavelength serves as the main prerequisite for plant growth and life. This takes 50% of solar radiation as the photosynthetically active light.

Amount of photosynthetic light absorption of the green vegetation and NDVI have direct relevance. FPAR refers to fraction of the incoming solar radiation. As proposed by Los (Los, 1998), FPAR measures the linear correlation (Formula: 3) of the NDVI (Normalized Difference Vegetation Index) and plant index simple ratio (Simple ratio). This method was applied by Zhu (Zhu et al. 2006) in China and Bao et al (Bao et al. 2016a) for measuring active solar (Zhu et al. 2006; Bao et al. 2016b), photosynthetic absorption of plant canopy in Mongolia. In order to calculate the realistic value for plant light absorption, maximum light use efficiency (g C/MJ), temperature stress coefficient and the photosynthetic process and precipitation stress coefficient are multiplied as shown in the following formula:

$$\varepsilon(x, t) = \varepsilon_{\max} \times T_{\varepsilon 1}(x, t) \times T_{\varepsilon 2}(x, t) \times W_{\varepsilon}(x, t) \quad (3)$$

In terms of calculation, ε_{\max} refers maximum light use efficiency expressed in g C/MJ, $T_{\varepsilon 1}(x,t)$, $T_{\varepsilon 2}(x,t)$ means temperature stress coefficients, $W_{\varepsilon}(x,t)$ to precipitation stress coefficients. Here, previously calculated ε_{\max} value (Bao et al. 2016b), values calculated for three major zones in Inner Mongolia (meadow steppe, steppe and desert-steppe), values for other categories and values identified by researchers, including Zhu and others (Zhu et al. 2006) (Table 1). Mongolia has four seasons, when the plant growth period lasts in April- October; this has been taken into account for selection of growth period (Bao et al. 2019).

2.2 Data used for the study

Grounded on the remote sensing and GIS methods, the research data, including Mongolia's vegetation map data, third generation GIMMS data from NOAA satellite, NDVI data, and Mongolia's climate data (average monthly temperature, total monthly precipitation, solar radiation intensity totals) for 1982-2015 (60 weather station and 14 solar monitoring stations) was processed. Meteorological datasets were represented and interpolated into raster images using kriging method and resampled to the same spatial resolution as other data (NDVI

raster etc.) inputs of the model. For the research, 1982- 2015 data from NOAA satellite (15- 16 days intervals), namely 34-year GIMMS-NDVI dataset with 8x8 km spatial resolution (Global Inventory Monitoring and Modeling System) was used, followed by processing. Latest version of GIMMS-NDVI data, a product of NDVI3g (third generation AVHRR sensor data GIMMS NDVI) dataset covering the period between July, 1981 and December, 2015. Based on 1:5000000 scale vegetation map, which is a part of the National Atlas of Mongolia- 2009, the relevant data was converted to raster data with 8x8 km spatial resolution, same as the plant indices and weather data. Finally, we used regression analysis (via SPSS, v. 19.0, Matlab) to estimate the correlations between the NPP or the observed NPP and meteorological data (precipitation and temperature). Researchers as Zhu (2006), Bao et al. (2016b), Bao et al. (2020) categorized the vegetation data in 6 groups, including coniferous forest, forest-steppe, typical steppe, desert steppe, Gobi desert and tundra-cushion in Table 1. Aforementioned vegetation types were used to determine the maximum light use efficiency.

	CF	FS	TS	DS	GD	TC
$\epsilon_{(max)}$	0.485	0.654	0.553	0.511	0.429	0.542

Table 1. ϵ_{max} values ($g\ C \cdot MJ^{-1}$) used for given biomes (CF: coniferous forest, FS: forest steppe, TS: typical steppe, DS: desert steppe, GD: gobi desert, TC: tundra & cushion).

2.3 Field measurement data

In order to verify NPP, which was calculated using CASA model, researchers carried out field measurement in area representative to forest-steppe, steppe and dry steppe zones collecting 14 aboveground biomass samples in July-August, 2007, 357 samples in 2009, 58 samples in 2014, and 142 desert steppe and desert are samples in 2015, totaling 571 samples, (1 x 1 meter area, respectively); and subsequently carried out calculations (Figure 1.). Above ground biomass went through over drying process at 60°C for estimation of dry biomass amount. As the CASA modelled NPP contains both above and below ground NPPs (Bao et al. 2016b), its AGB value (Gill et al. 2002) was converted to NPP complying with the proposed method and the calculation found that BGB was 5.26 in meadows and 6.76 in steppe as opposed to AGB (Bao et al. 2016a; Piao et al. 2007). AGB was converted using 0.475 conversion coefficient to ANPP (Scurlock et al. 1999).

2.4 Study area

Mongolia is located in the southern part of Siberian taiga region and in the north of Central Asian arid desert, stretching vast area between Altai, Khingan and Khangai Mountain Ranges. With immense territory, Mongolia's average elevation is 1580 meters above the sea level, surrounded by mountains in west, north and north-east.

It is characterized by its extreme Eurasian continental climate, which results in changeable weather showing high degree of difference between annual and daily temperatures. Low precipitation, dry and long winter. Average annual temperatures are around -7.8°C in the high mountainous and 8.5°C in the Gobi areas (MNET. 2014). The annual total precipitation is around 400 mm in the mountainous areas in the north, 250–300 mm in the forest steppe regions, 150–250 mm in the steppe regions and less than 100 mm in per year in South (Gobi Desert) region (Dorjsuren et al., 2016).

Rangeland accounts for over 80% of Mongolian territory, and the rangeland has been used for thousands of years for grazing; therefore, it is vital to determine its evolution and perspectives.

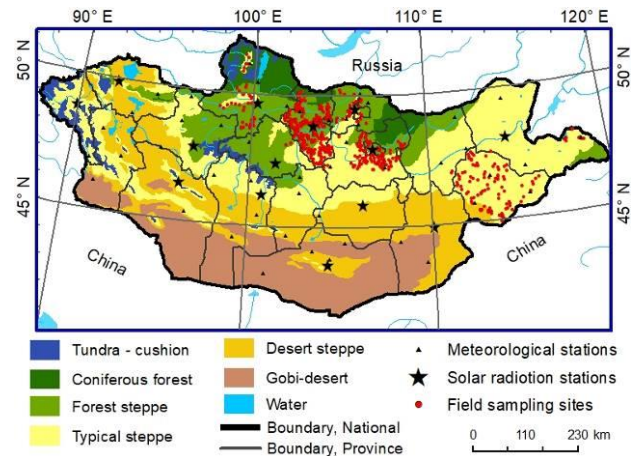


Figure 1. Study area and the distribution of vegetation types, meteorological stations and field sampling sites.

3. RESULT AND DISCUSSION

This research calculated the NPP of vegetation in Mongolia covering the period of 1982-2015. In Mongolia, depending on the natural zone and spatial distribution of precipitation, average value for past 34 years keeps declining as it goes from north to southwards in Figure 2. According to multiple-year average, it fluctuates between 166.1 $g\ C/m^2$ and 19-724.85 $g\ C/m^2$. The highest value was observed in northern Mongolia, where high mountains, forest, meadows and steppe dominate, with average NPP of 442.4 $g\ C/m^2$. Whilst, the average for steppe zone that takes majority of Mongolia's territory, was found 208.6 $g\ C/m^2/year$. Land that contains globally important biodiversity (Blench and Sommer.1998) and rangeland store 30% of earth's carbon (Grace et al. 2006).

In Mongolian climate, humid air from seas significantly reduce or lost due to geographic location, solar energy, atmospheric moves, landforms, isolation from seas, location in northern dry hemisphere and surrounding mountains; subsequently NPP distribution and amount vary from region to region. In the high mountain areas and forest zones, vegetation cover is dense due to high precipitation, where the highest NPP was recorded. In some parts of Mongolia with higher precipitation, including Khangai and Khentii Mountain Ranges, respectively, Khantai mountain range in the northern part of Bulgan province, and Buteel Mountain Range- forest zones of Mongolia- where the total annual precipitation reaches 300- 400mm or more, vegetation NPP found to be 400-500 $g\ C/m^2/year$, with the higher NPP value of 643.9 $g\ C/m^2/year$ in some mountains and taiga zones in Figure 2. Moreover, east, south east and Great Khingan mountain areas have 250- 300mm precipitation and NPP 350-500 $g\ C/m^2/year$ due to strong influence from Pacific Musson wind. Driven by characteristics of natural and geographical zones, NPP value starts decreasing from the alpine and forest zones, e.g. from north to southwards and west to eastwards. This pattern is caused by the landscape condition that the country stretches over desert-steppe and Gobi desert in south and south-west, low precipitation in these zones and sparse vegetative cover. Also, 250- 300mm precipitation comes in south and west of Khangai Mountain and north of Baga Khentii and Bulnai mountains, per year, where the NPP value of 300-400 $g\ C/m^2/year$, while 150- 250mm drops in Eastern Mongolian steppe, Dariganga plateau, major crop planting areas and steppe zones with annual average NPP of 200-300 $g\ C/m^2/year$.

C/m²/year. Places with the lowest NPP were Great Lakes Depression, Valey of Lakes, Southern Altai Gobi, Dundgobi, Umnugobi and eastern part of Dornogobi provinces, as well as Gobi desert region with the average value of 0-50 g C/m²/year and even lower in some parts. In Gobi desert, annual precipitation is lower with 50-100 mm, and even lower in some years.

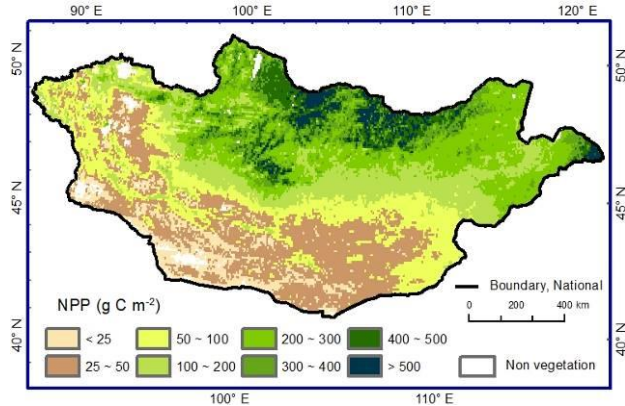


Figure 2. Spatial distributions of 34-year average growing season NPP

3.1 Comparison between the model and observed value

Comparing the model with the observed data is the most optimal way for verification. As the satellite image covers wide area (pixel size), it is often found difficult to compare against the data collected from the field. The reason is that measured data and remote sensing data don't always overlap in terms of timing. In addition to taking account the potential errors, which may occur CASA model, which used GIMMS NDVI and field measurement (Mu et al. 2009) and (Wang et al. 2017), CASA's accuracy rate ($R^2=0.62$) makes it possible for research on fluctuation of vegetation NPP, but it is impossible to directly measure without remote sensing in studying NPP of a specific area and climate barriers. Notwithstanding the erroneous calculated value of NPP in the previous studies, methodology, data entry and observation period (Blench and Sommer.1998) and (Grace et al. 2006) may differ, but the general links found in the previous studies indicate that CASA model can be used for studied taking place for years. From this, changeability and trends of NPP in Mongolia can be observed well. Further on, we used NPP data and verified the accuracy of CASA model in the northern and eastern part pasture in Mongolia in Figure 3 and Table 2. The results shows the following determinant coefficient between modelled and observed NPP values; in 2007, ($R^2=0.74$ ($p<0.001$) and root-mean-squared-error (RMSE) 14.9 g C/m²; in 2009, ($R^2=0.71$ ($p<0.001$) and RMSE 15.17 g C/m²; in 2014, ($R^2=0.73$ ($p<0.001$) and RMSE 19.34 g C/m²; and, in 2015, ($R^2=0.71$ ($p<0.001$) and RMSE 14.9 13.23 g C/m². If this values are compared to Inner Mongolian steppe values, which has similar conditions as the research field, the value were similar to those identified by Bao et all (Bao et al. 2019), and Mu et all, (Mu et al. 2013a) and (Mu et al. 2013b).

Years	R ²	SD	PC	P	Sample number
2015	.718	13.23	.847	.001	142
2014	.730	19.34	.855	.001	58
2009	.711	15.18	.843	.001	357
2007	.742	14.90	.861	.001	14

Table 2. Comparisons between the modeled and field observed net primary productivity

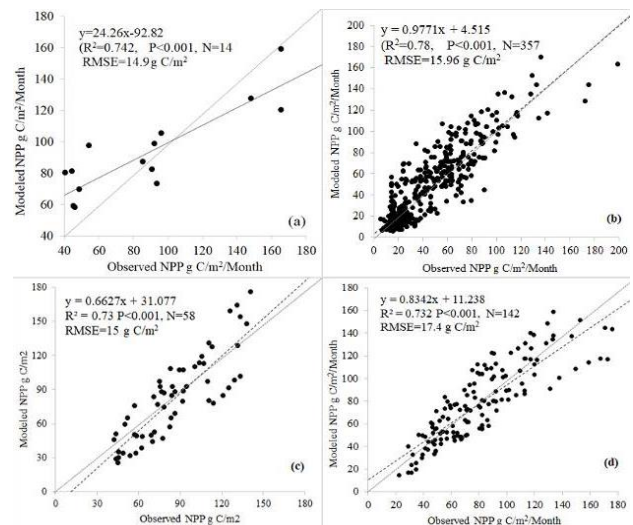


Figure 3. Comparisons between the modeled and field observed net primary productivity., a) 2007, b) 2009 c) 2014 d) 2015

3.2 Temporal and spatial changes in vegetation NPP

The research calculated the vegetation NPP for 34 years, covering 1982-2015, focusing on the main growth period of vegetation, outset of April to October., followed by referencing in the curves and illustrating in the Figure 4. From the statistics on the total NPP (the sum of NPP in all pixels, its unit is P g C) and annual NPP (the NPP per unit area, its unit is g C/m²/year) in Mongolia (Figure 4), it was observed that the change trends of total NPP and annual NPP from 1982 to 2015 are similar, both presenting an increasing trend in fluctuation.

The total NPP and annual NPP were from 0.27 to 0.39 Pg C, 547.91 to 724.85 g C/m²/year, their average value is 0.32 Pg C and 642.3 g C/m²/year (Table 3). That total NPP value during plant growth period declined by 0.03 P g C/m²/year from 1982 to 2015. NPP declined slowly from 1990 to 2007 and increased from 2008 to 2013 (Figure 4).

	Total NPP	annual NPP
Min	0.27	547.91
Mean	0.32	642.32
Max	0.39	724.85
SD	0.03	34.81

Table 3. Total NPP and annual NPP (1982-2015)

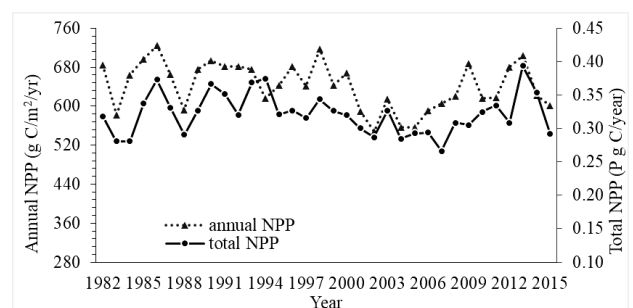


Figure 4. NPP trends during 1982-2015 (g C/m²/year)

Over the last 34 years, NPP has increased by 2 g C/m²/year in eastern, and by 1 g C/m²/year in some parts of the south and southwest and central part of the Mongolia. But in the northern part of forest-steppe area it's decreased by more than 3g C/m²/year (Figure 5).

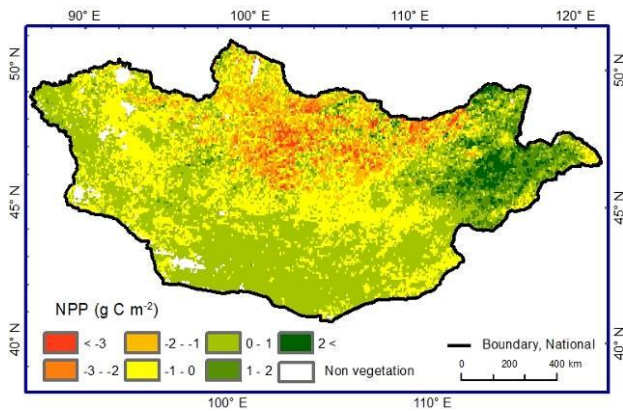


Figure 5. NPP changes during 1982-2015 ($\text{g C/m}^2/\text{year}$)

3.3 Climate respons on vegetation productivity

The inter-annual changes of the mean annual NPP in Mongolia are shown in Figure 6a. Overall, the mean annual NPP showed fluctuating from 1982 to 2015, with general declined trend ($r=0.08$, $p=0.11$). However, the inter-annual variation of NPP was not consistent over the entire study period, but showed two distinct stages. It can be clearly observed that the NPP experienced a decreasing trend from 1986 to 2002 ($r=-0.58$, $p<0.01$) and it then representing increased trend between 2002 and 2013 ($r=0.81$, $p<0.01$).

The spatial pattern of the annual NPP trends in the past 34 years is shown in Figure 6b. A positive correlation was observed between annual NPP and precipitation ($r=0.7$, $p<0.01$) during 34 year. This indicates that increased precipitation led to increased NPP for vegetation. Precipitation in the same way as for NPP experienced a decreasing trend from 1986 to 2004 ($R=-0.64$, $P<0.01$) and then sharply increased between 2004 and 2013 ($r=0.85$, $p<0.01$). This indicates that increased precipitation led to increase of NPP. The statistics on the mean temperature in Mongolia observed that the change trends from 1982 to 2015 (Figure 6c) presenting increasing trend in fluctuation ($R=0.46$, $P<0.01$).

In specific areas of Mongolia with higher precipitation, in the northern part, where the total annual precipitation reaches 300-400 mm or more, vegetation NPP found to be 400-500 $\text{g C/m}^2/\text{year}$, with the highest NPP value of 724.85 $\text{g C/m}^2/\text{year}$ in some mountains and taiga regions. In the Gobi region, multiple year NPP was found 50 $\text{g C/m}^2/\text{year}$, and even lower in some areas. In Gobi desert zone, average annual precipitation is low with 50-100mm, even lower in some years.

Which means that NPP on Mongolia has direct dependence on the precipitation. The correlation coefficients for the annual NPP and the annual accumulated precipitation in each pixel between 1982 and 2015 were calculated. The correlation analysis between the precipitation and vegetation productivity unveils approximately 60% of Mongolia's vegetation productivity heavily relies on precipitation as evidenced by determination coefficient $R^2=0.79$, confidence $p<0.001$, and correlation coefficient $R=0.88$ (Figure 7).

During past 34 year, average temperature in the research area increased by 1.5°C whilst the precipitation declined by 7.3% (Figure 6). The most areas NPP have negative relevance with temperature ($R=-0.38$, $P<0.001$) and it has NPP were significantly dependent on precipitation (Figure 7).

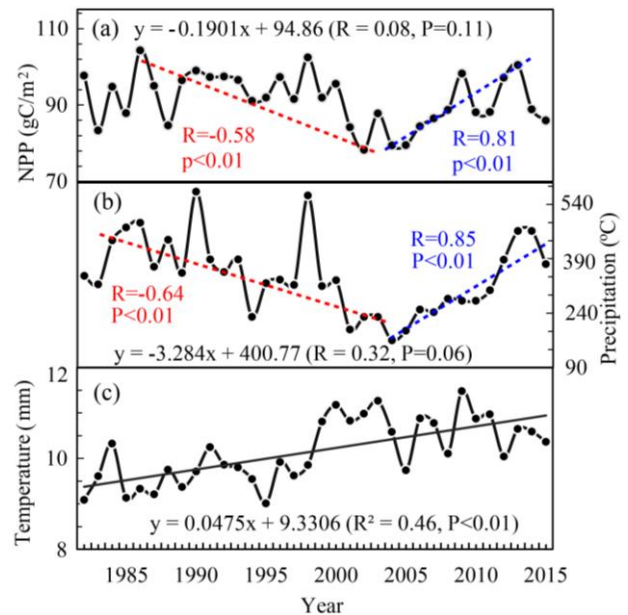


Figure 6. Annual variation of NPP and climate parameters in Mongolia from 1982 to 2015: (a) mean annual NPP; (b) annual accumulated precipitation; and (c) annual mean temperature. Decreased trend by red lines and increased trend by blue lines with the linear regress for each stage.

There were notable spatial differences in the correlation coefficients between the mean NPP during the growing seasons and the annual temperature and precipitation. In general, NPP was negatively correlated with air temperature and positively correlated with precipitation in the most part of Mongolia ($r=0.6-0.8$, $p<0.01$) (Figure 8a).

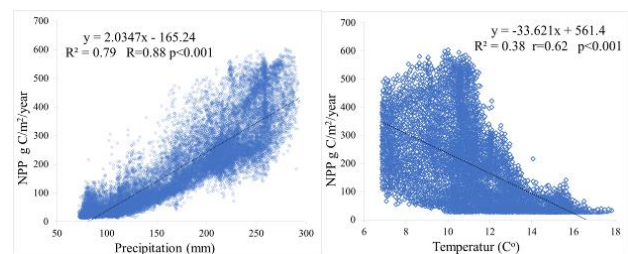


Figure 7. Correlation between average growing season NPP a) precipitation, b) temperature during 1982-2015.

NPP was positively correlated with air temperature west and east of Lake Hovsgol ($r=0.2-0.4$, $p<0.01$), eastern part of the Selenge river ($r=0.2$, $p<0.01$), and center part of the Dornod province in Mongolia ($r=0.2-0.4$) (Figure 8b). NPP value decrease gradually shift down to southwards of Mongolia. That kind of decline pattern is heavily influenced by terrestrial landscape (concave and convex landforms), which limits precipitation distribution, on the other hand, dominant steppe and deserts areas in south and south-west create the vegetative cover and precipitation sparse and scarce.

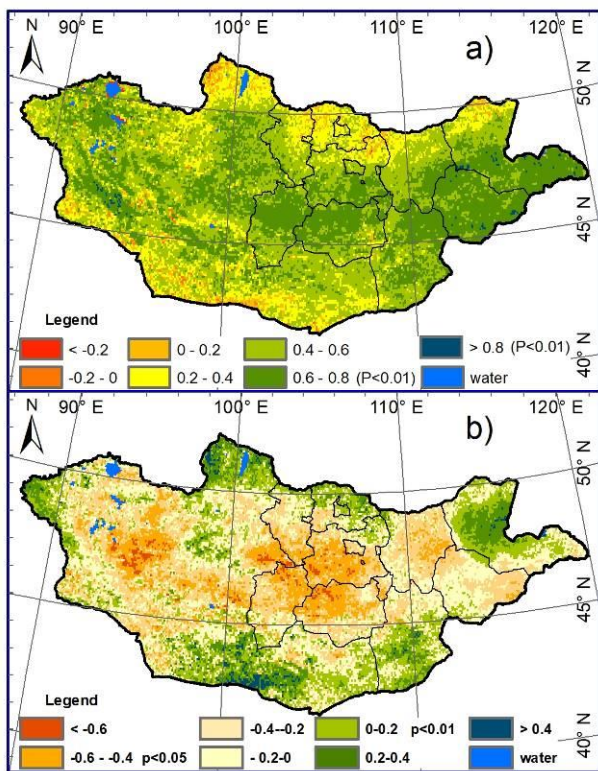


Figure 8. Spatial correlation a) precipitation and NPP b) temperature and NPP between 1982-2015.

4. CONCLUSIONS

During the past years, global warming has taken place speedily, whilst its impact has been imposed to Mongolia three times more than the average as evidenced by reduced precipitation and increased effect on the rangeland vegetation. Within the framework of this research, vegetation NPP during the plant growth period for 34 years covering 1982- 2015 grounded on ecosystem CASA model using relevant data, such as Mongolia's pasture plant carbon absorption capacity, carbon storage, light use efficiency coupled with satellite data, climate data and other necessary datasets. For the research, maximum light use efficiency was measured in meadow-steppe, steppe and steppe-desert zone plants for the CASA model. Relevant analyses indicate that 34-year average NPP declines as it goes from north to southwards due to natural zones and spatial distribution of precipitation. According to multiple-year average, NPP value fluctuates between 166.1 g C/m² and 724.85 g C/m², with the maximum NPP value observed in northern Mongolian alpine, forest, meadow and steppe zones, NPP 442.4 g C/m² being the average. NPP evaluation methodology was found more consistent with the reality when the relevance of model value was tested and mean squared error was calculated using field survey data from 2007, 2009, 2014 and 2015, respectively. Total vegetation during plant growth period of 1982-2015 dropped by 0.03 P g C/year from 0.32 P g C/year in 1982 to 0.29 P g C/year (1Pg=10¹⁵g) in 2015. Research has proved that the NPP in Mongolia is severely dependent on precipitation due to seasonal variations. Correlation analyses on the precipitation and vegetation productivity unveils approximately 60% of Mongolia's vegetation productivity heavily relies on precipitation as evidenced by determination coefficient R²=0.79, confidence p<0.001, and correlation coefficient R=0.88. Whilst, the NPP shows negative relevance with temperature in most parts of the country, e.g. central Mongolia and south-east of Great Lakes Depression in western

region have significant relevance, and these areas also have dependence on precipitation.

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