Drought research in Mongolian plateau

D.Altantuya, Bao Yu Hai, Bao Gang, С. Шийрэв-Адъяа

Institute of Geography and Geo-ecology, Mongolia
email; altantuya.gis@gmail.com

Abstract

The term “drought” is the natural disaster which is caused by large amount of evaporation due to long term of dryness and it affects the nature and social economy in bad ways like shortcoming of plants due to low moisture in the soil and lack of surface water resource. Drought can also be explained as it is the one kind of atmospheric disaster that can affect the pastoral cattle breeding and plant cover.

The research was done focusing the diverse drought amount and diverse extensional and periodic dispersion based on precipitation data of the Mongolian Altitude (Mongolia and Inner Mongolia Autonomous Region) of total of 31 years from 1980 to 2010 performed by 108 weather stations using method SPI as modeling the GAMMA dispersion function. The estimation of SPI for the period of 31 years from 1980 to 2010 of Mongolian Altitude shows that the drought is mainly dispersed in spring and summer times in areas including Khangai range; Bulgan, Selenge, Uvurkhangai, Tuv provinces which are south parts of Khentii range; from Northeast to the west - cavity of Grand Lakes, Dornogobi, South gobi of Altai, Alshaa, Ordos; in the southeast – Tung Liao, Chi Feng cities. The most serious dispersion year was 1981 and the SPI was “-2.57” in certain section of area from west to southeast till Alshaa province. In the spring and fall times, the drought intensification was higher in areas from west-north to south-east and from north-east to the center.

The most serious drought year was 1980 and SPI was equal to -2.501 and disperse was through the areas of south-west including Gobi-Altai, Bayankhongor, Alshaa and south part of Khulunbuir.

This natural order is relative to dry climate of Mongolian Altitude as well as sparse vegetative cover and low precipitation in the regions of south-west and south parts regarding their parched and deserted condition. Mongolian Altitude exists covering wide range of land and several regions along latitude from north to south. It is relatively different as for the space, earth surface, thus the drought period and its frequency is also different.

Study for evaluation of drought has contained the drought affecting scope, duration and the level and drought disperse. Also it has included drought condition in the research regions in the spring, fall and summer times.

1.Introduction

Since 1960’s desertification and drought areas have been expanding and such situation has been an actual problem worldwide. Especially, global climatic changes and human actions have been resulting in deterioration of nature and environment, soil erosion, rangeland degradation, desertification, dust storm, flooding, dust formation, and greater occurrence of both drought and zud for the last 50 years.

Global warming started since 1980’s and there is a tendency of decreasing the precipitation rate in Mongolian plateau. In turn it is becoming a reason of making the drought heavier.

Mongolian plateau is mountainous in west, northern west and southern east areas, very far from the oceans, higher fluctuations of precipitations and air temperatures, severe continental and very arid climate with characters of Gobi and desert, as well as very susceptible to global climatic changes. Relying on the data of precipitations and temperatures from 1980 to 2010 in Mongolian plateau, standardized precipitation index (SPI) was estimated and both spatial and temporal distributions, changes and tendencies were investigated. Therefore, our study aimed to choose warm seasons including spring (from March through May), summer (from June through August) and autumn (from September through November) and estimate and conclude the drought situations in each seasons.

2.SPI method and research data

2.1 SPI method

Standart Precipitation Index (SPI) developed by McKee et al in 1993 aimed to monitor droughts. SPI stand for standardized precipitation index. It means first of all that distribution of precipitation is governed by GAMMA distribution a cording to Tom et al (1960). Then the precipitation change is illustrated with GAMMA distribution possibility. Finally, SPI should be calculated on the basis of normative standard.

SPI is of flexible nature and able to investigate the changes of precipitation rates in the different times and areas. As well, it is also suitable for analyzing the index of drought encompassing large areas. SPI is calculated with the following formula:

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta}$$

$$A = \text{In}(\bar{x}) - \frac{1}{n}\sum In(x)$$

In above formula, the value n is the number of precipitation observations and therefore cumulative probability , where x is the precipitation amount, is given by:

$$G(x) = \int_0^x g(x)dx = \frac{1}{\hat{\beta}^{\hat{\alpha}}\Gamma(\hat{\alpha})}\int_0^x x^{\hat{\alpha}-1} e^{-x/\hat{\beta}} dx$$

If it is $t = \frac{x}{\beta}$, this equation is expressed with indefinite GAMMA function or the following equation:

$$G(x)=\frac{1}{\Gamma(\alpha)}\int_0^t t^{\alpha-1} e^{-t}\, dt$$

Although GAMMA function is defined by this formula, it is not complete/
GAMMA function is not defined for X=0, within IDL and cumulative precipitation is in below form when precipitation distribution includes the zeros.

$$H(x) = q + (1-q)G(x)$$

when q - precipitation within the series is zero in each case of zero precipitation and the ratio of temporal series length, cumulative probability distribution function H(x) is:

$$H(x) = \frac{1}{\sqrt{2\pi}}\int_0^{\infty} e^{-z^2/2}\, dx$$

During earlier period pictures were used for determination of Z variable or SPI, and since 1965 Abromowitz and Stegun proposed easier approach of estimation.

When $0 < H(x) \leq 0.5$

Z=SPI=

$$-[t-(c_o + c_1 t + c_2 t^2)/(1 + d_0 + d_1 t + d_2 t^2 + d_3 t^3)]$$

$0.5 < H(x) \leq 1.0$

Z=SPI=

$$+[t-(c_o + c_1 t + c_2 t^2)/(1 + d_0 + d_1 t + d_2 t^2 + d_3 t^3)]$$

$0 < H(x) \leq 0.5 \quad t = \sqrt{In(1/(H(x)))}$

$0.5 < H(x) \leq 1.0 \quad t = \sqrt{In(1/(1-H(x)))}$

CO=2.515 517, C1=0.802 853, C2=0.010328,
d1=1.432 788, d2=0.189269, d3=0.001 308

Using ENVI and IDL software of remote sensing based on above formula, each season is divided with drought intensity.

2.2 Research data

In the present study, Mongolian plateau, encompassing a total of 2.74 million square km area of northern Central Asia was considered.

Monthly total precipitation and average temperature as the point data from a total of 108 stations of both Mongolia and Inner Mongolia were used in the study.

Processed precipitation data were divided into magnitudes of dryness of drought within IDL using ENVI software and calculated with SPI method.

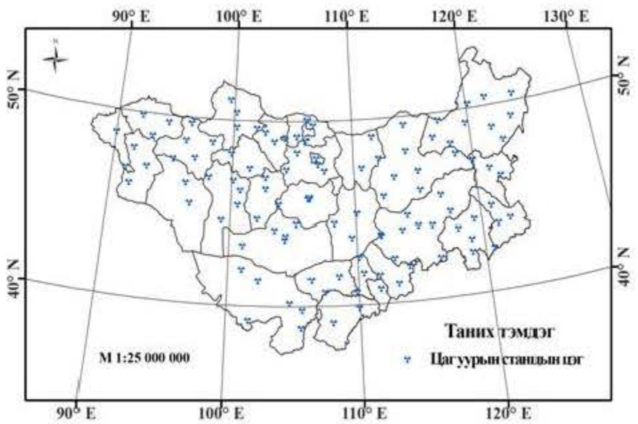

Figure 1. Localizations of meteorological stations of in Mongolian plateau

3.Results of the study

3.1 Spatio-temporal variability of drought

In the present study, results calculated by SPI method for drought conditions of Mongolian plateau from March to November for the last 31 years are presented. In order to clarify drought conditions in the below illustration, each year is given in different colors and drought distributions are demonstrated.

Extreme drought in spring season for 31 years SPI values are relatively variable. Year of the most severe drought was 1981, when SPI value reached -2.57 and the minimal measure was -2.036 in 1993. Extreme drought distributed in western and central areas of Mongolian plateau (figure 2) in 1980's, whereas it distributed in Bulgan, Selenge and Tuv aimags of northern part and Alshaa province and southern Ordos areas of southern part of Mongolian plateau in 1990's, and almost all part of Jirem province, northern west of Ulaankhad province, as well as Bayan-Ulgii and northern Gobi-Altai aimags of western Mongolia in 2000's.

Extreme drought during summer season for 31 years SPI values are relatively variable. Year of the most severe drought was 1981, when SPI value reached -2.56 and the minimal measure was -2.008 in 1994. Summer (figure 3) extreme drought areas were in western and central parts of Mongolian plateau in 1980's, around Bulgan, Selenge, Tuv aimags and smaller part of Khuvsgul aimag as the northern regions, and southern parts including Alshaa and southern Ordos in 1990's, while in western and southern east parts duirng 2000.

Extreme drought during autumn season for 31 years SPI values are relatively variable. Year of the most severe drought was 1980, when SPI value reached -2.501 and the minimal measure was -2.015 in 1993. Autumn extreme drought areas (figure 4) were in western and central parts of Mongolian plateau in 1980's, northern west, southern west, central, southern and southern east regions of Mongolian plateau in 1990's, while northern east and central parts of Mongolian plateau in 2000.

Severe drought of each season in Mongolian plateau tends to be greater than spring season in terms of total areas or intensity and spatial difference is also higher. Years when spring and summer seasons reached -2.5, are 1981, 1989 and 2004.

SPI value of 31 years for spring and summer severe drought is -1.739 in 1983, minimal SPI value in 2001 is -1.528. Spring season drought (figure 5) distributed in western and northern parts of Mongolian plateau and encompassed southern east and central parts, while it distributed in southern east and northern parts in 1990's. In 2000, it distributes southerm eastern and northern west parts of Mongolia.

Maximal SPI value of 31 years for autumn severe drought (figure 7) is -1.808 in 2007, whereas minimal value is -1.523 in 2010. Generally it distributes throughout all territory.

3.2 Changes of average SPI values of each drought season

It is possible to measure such parameters as drought intensity, distribution and drought start and end periods based on precipitation data.

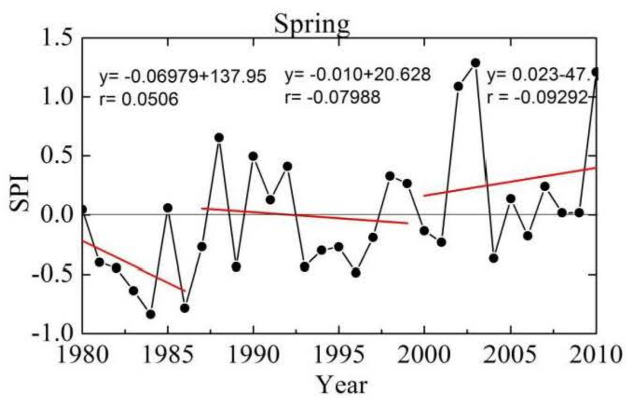

Figure 2.Yearly average SPI of spring season in Mongolian plateau

SPI average values between 1980 and 2010 in Mongolian plateau were compared with each spring, summer and autumn seasons.

From the graph in figure 2 it is shown dryness variability for the last 31 years is greater. SPI average value of spring season demonstrates for 31 years droughts occurred in the years 1983, 1984, 1986, 1989, 1993, 1996, 2000, 2001, and 2004, and the drought lasted in spring season in 1983 and 1984. As well, drought increased with intensity of -0.06979 until 1980 – 1986, while it was observed drought conditions were slightly decreased by -0.010 or almost symmetrical in 1987-1999, while there was a tendency of decreasing by 0.023 in the years 2000 – 2010.

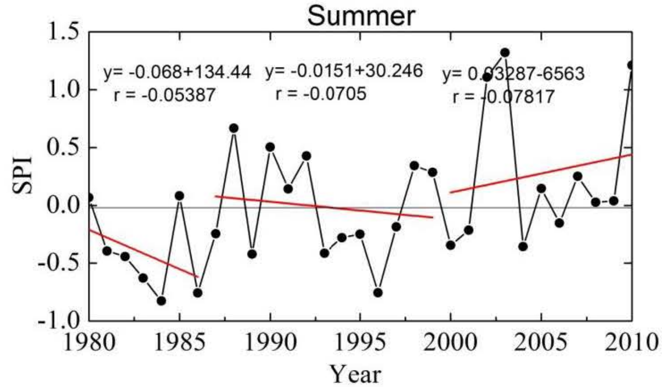

Figure 3. Yearly average SPI of summer season in Mongolian plateau

Summer season SPI values of the graph in figure 3 shows continued droughts were in 1983 and 1984 and drought occurred in 1986, 1989, 1996, 2000, 2001, and 2004. During summer in 1980-1986, drought condition was intensively increasing by 0.068, and it was negligibly increasing by -0.0151 or almost symmetrical in 1987-1999, whereas drought condition was decreasing by 0.03287 in 2000 to 2010.

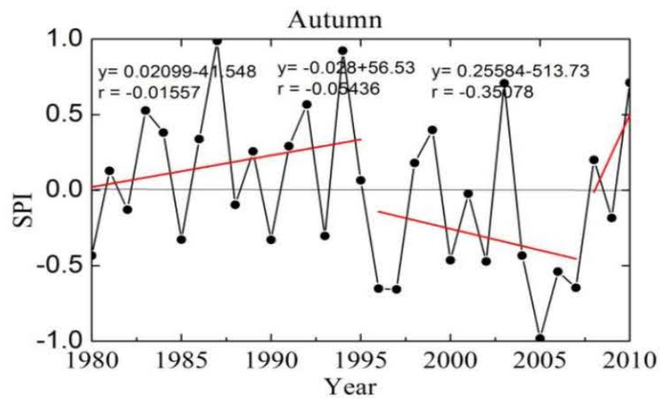

Figure 4. Yearly average SPI of autumn season in Mongolian plateau

Autumn season SPI values variation of the graph in figure 4 shows drought years were 1996, 1997, 2005, 2006, and 2007 and continued droughts were in 1996, 1997 as well as 2005, 2006 and 2007. Apparently there is a tendency of slight decrease, but relatively even patterns were found from 2008 to 1995, drought condition became severe from 1996 to 2007, while a tendency of decrease reappeared in 2008-2010.

3.3 Effect of air temperature on drought

Relationship between drought and both precipitation and air temperature in the last 31 years was investigated.

Data of precipitations and air temperatures measured at 108 meteorological stations were used. According to estimation with the averages of monthly precipitation sum and air temperatures measured by 108 stations from March to November between 1980 and 2010, a tendency of increasing air temperature and decreasing precipitation was observed in the last 30 years. Both were at multi-year norm, but they fluctuated depending on annual climatic conditions in 1980-2010, precipitation was decreasing and temperature increasing from 1994. Therefore both changes are in good agreement with that drought index increases in 1980 -2010, has no significant changes and then increases rapidly.

Conclusion

Although drought extents in both spring and summer seasons are almost same in Mongolian plateau, drought condition is tended to encompass larger areas in spring season.

Drought conditions distribute broadly from northern west part to Great lakes hollow, Altai southern gobi, Alshaa province and southern east part, as well as northern part the area including areas of Tuv and Selenge aimags, and southern part Khangai and Khentii mountains, central part including Uvurkhangai and Dunfgobi aimags, and Tung Liao and Chi Feng cities in southern east part.

Drought intensity is higher from northern west to southern east including some parts of western aimags, Mongol-Altai and Gobi gurvan saikhan to Alshaa province, Ordos, whole part of northern Ordos, and from northern east to central part including eastern Mongolia steppe, Sukhbaatar and Dornod aimags and around Ulaankhad in southern steppe of Shiliin gol province. Because this principle differs with space and land surface, intervals between drought occurrences and their frequency are also different.

Occurrences of severe droughts in spring and summer seasons in Mongolian plateau between 1980 and 2010 were investigated, drought affected areas were the largest in 1981, 1982, 1983, 1984, 1989, 1996, 2000, 2003 and 2004, and drought affected areas decreased by -0.34 in spring and -0.36 in summer for the last 31 years. For autumn season, severe drought occurred in 1980, 1986, 1993, 1995, 1997, 2004, 2005, 2006 and 2007, and drought affected areas tended to increase by 0.1724 for the last 31 years.

References

[1] [13] Bayasgalan B., Natsagdorj L, 2004. Applicability of Standardized precipitation index for assessment of atmospheric drought in the territory of Mongolia. Research Publication of Hydrological and meteorological institute, №26, p 56-67

[2] Vandandorj S., Gantsetseg B, 2013 "Possibility of imaging the droughts and summer patterns by using satellite data, Ecology-2013, Proceedings of Conference "Ecology-2013

[3] 卓义，基于遥感与 GIS 技术的内蒙古东部草原地区干旱灾害监测、评估研究，中国农业科学院博士论文，2011

[4] 李慧静，包玉海，包刚，等基于MODIS-NDVI的内蒙古植被变化遥感监测[J].测绘科学，2009，34（5）