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The use of Standardized Precipitation Index values (SPI) and MODIS vegetation indices to assess drought of steppe regions, Algeria

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Abstract. Drought events were assessed using remote sensing index MODIS (MODerate resolution Imaging Spectroradiometer) and Standardized Precipitation Index (SPI) over the steppe regions of Algeria between 2000 and 2012. In this study, the Vegetation Condition Index (VCI) and Temperature Condition Index (TCI) were determined from Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The VCI (Vegetation Condition Index) was based on the Normalized Difference Vegetation Index (NDVI) datasets. The TCI (Temperature Condition Index) was derived from land surface temperature (LST) datasets. The VCI and TCI were then combined to calculate the Vegetation Health Index (VHI). Also, the one-month Standardized Precipitation Index (SPI) data from rainfall stations in the study area was calculated. The results show that years of normal condition (least drought) were year 2006, 2009, 2010 and 2012. However, all indices recorded a drought with different classes for 2000, 2001, 2002, 2003, 2004, 2005, 2007, 2008 and 2011 can be considered unusual conditions. According to the results obtained from this study, a large part of the study area is located in severe of drought classes that likely is related to the rainfall reduction and topographic characteristics of the area and poor vegetation, which need more attention to water resource management in this region.

Keywords. Drought, MODIS sensor, SPI, steppe regions, Algeria.

1. Introduction

Algeria is one of the African countries is characterized by spatial and temporal variability in climate. This variability is determined by a low annual rainfall and a high intra and inter-annual variability of rainfall. Over the past decades, Algeria has suffered from several episodes of drought endangering agricultural production and confronting pastoralists with water and fodder shortages. These drought situations lead to the degradation of the living conditions of the populations and of the environment. Drought is a natural disaster which causes global damages and affects people. Drought is caused naturally by the deficiency of rainfall over a prolonged period in an area, in which the lack of natural water availability leads to temporary deficiency [1].

Totally, Drought can be classified into meteorological, agricultural and hydrological and socio-economical drought [2], these consequences negatively affect the economic and social

life of the people [3]. Drought is a natural hazard due to adverse climatic changes which affects various sectors like environment, society and economy. It occurs not only because of the scarcity of rainfall but also due to the inefficient water resource management. The United Nations Convention to Combat Desertification (UNCCD 2022) [4] estimated that in the last 40 years, 12 million hectares of land have been lost to drought. By 2050, it is estimated that drought may affect over three-quarters of the world's population.

The technological evolution in remote sensing over the past few decades has opened a new era in the field of drought monitoring. Thus, use of remote sensing and GIS helps in developing early warnings about drought conditions which will be useful for planning the strategies for relief work. Remote sensing and GIS have been widely used for both model-based drought monitoring and climate impact assessment at regional and global scales. During recent decades, remote sensing has proven to be an indispensable tool for achieving drought studies over large areas and in near real time [5]. Several remotely-sensed drought indices have been developed and applied to assess drought conditions such as NDVI, LST, PCI, VCI, TCI, SMDI, VHI, PSDI, TVDI, VSDI.

One of these, the Normalized Difference Vegetation Index (NDVI) has been one of most usually used approaches to drought episode monitoring and as a probe for vegetation health [6]. Vegetation indices determined by remote sensing were examined by many recent studies. Vegetation Health Index (VHI) has been applied in drought detection, drought severity and duration, early drought warning [7]. Meteorologically, drought monitoring can be conducted with various methods. One of the methods used is by knowing the SPI (Standardized Precipitation Index). SPI method is the rainfall unit occurring under normal condition in such a time scale. Beside meteorologically monitoring, it can also be monitored based on the spread of vegetation influencing the availability of water supply which can be seen from the VHI (Vegetation Health Index) value. In this study MODIS images are used to assess the vegetation change and agricultural drought in steppe regions. Agricultural drought indices (NDVI, VCI, TCI and VHI) and meteorological precipitation index (SPI) are calculated from 2000 to 2012, the remote sensing findings are compared to meteorological data to estimate relationship between them.

2. Material and method

2.1 Study area

The Algerian steppes, located between the Tellian Atlas to the north and the Saharan Atlas to the south (Figure 1), cover a total area of 30 million ha or 12.6% of Algerian territory. Average elevation of Algerian steppes district with respect to mean sea level is 1200 m. The climate of the study area is semi-arid and is strongly marked by a continental influence, with cold, wet winters and hot, dry summers. They are located between the 400-mm rainfall isohyet to the North and 100 mm-rainfall isohyet to the South. According to Nedjraoui and Bedrani (2008) [8], the steppe regions constitute a buffer between coastal Algeria and Saharian Algeria, of which they limit the negative climatic parameters influencing aridity in Algeria are rainfall intensity and frequency, which are conditioned by two geographical gradients.

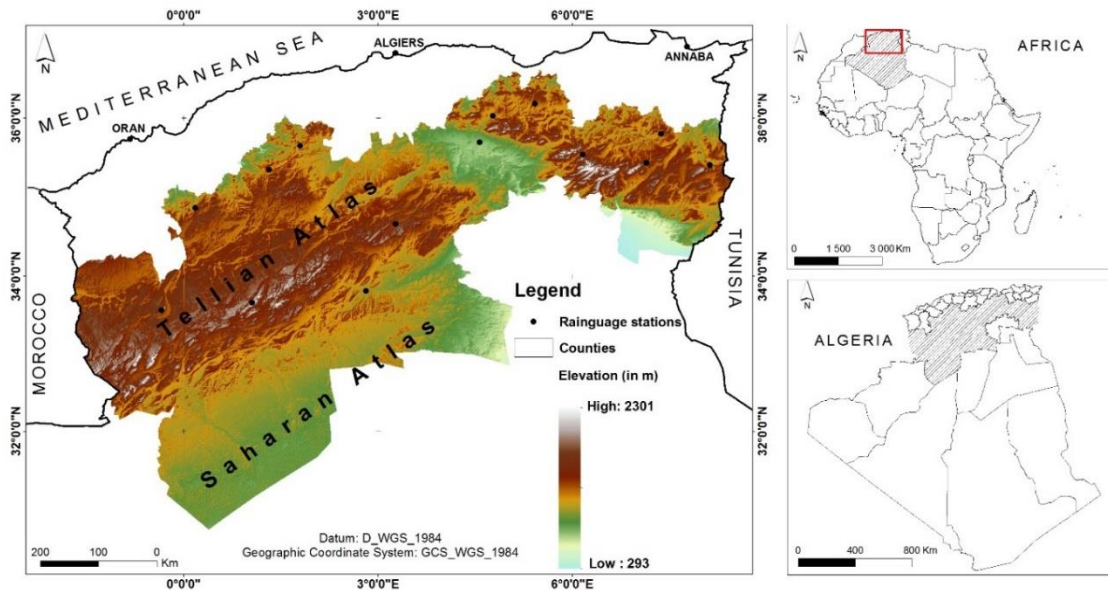


Figure 1. Localization of the studied area

2.2 Database

2.2.1 Climate data

This study used the monthly average precipitation were measured by National Meteorological Office – Fr. Office National de la Météorologie (ONM) and National Agency of the Hydraulic Resources – Fr. Agence Nationale des Ressources Hydrauliques (ANRH). The location and spatial characteristics of the stations in the steppe regions are shown in figure 1 and table 1. The selected positions are based on criteria of continuity, duration of available information, and data quality, the time coverage of the data is 2000–2012. These data were used to calculate the SPI. The SPI, calculated by using the historical rainfall dataset, was considered to quantify the meteorological drought.

Table 1. Geographical coordinates of the weather stations used in this study

Stations	Bioclimate	Latitude	Longitude	Altitude(m)	Period	Average(mm)
El-Bayadh	Semi-Arid	33°40' N	01°00' E	1341	2000–2012	281,48
Djelfa	Semi-Arid	34°20' N	03°23' E	1180	2000–2012	276,08
Mecheria	Semi-Arid	34°31' N	00°17' W	1149	2000–2012	254,63
Saida	Semi-Arid	34°52' N	00°09' E	0750	2000–2012	380,08
Laghouat	Pre-Saharan	33°77' N	02°93' E	0765	2000–2012	155,16
M'Sila	Arid	35°40' N	04°30' E	441	2000–2012	214,68
Nâama	Arid	33°16' N	00°18' W	1166	2000–2012	286,57
Tebessa	Semi-Arid	35°25' N	08°07' E	821	2000–2012	408,53
Batna	Semi-Arid	35°43' N	06°21' E	822	2000–2012	408,75
Tiaret	Sub-Humid	35°21' N	01°28' E	977	2000–2012	544,60
Ain El Beida	Semi-Arid	35°47' N	07°23' E	1004	2000–2012	432,46
Khenchela	Semi-Arid	35°28' N	07°05' E	983	2000–2012	493,66
Bordj Bou Arreridj	Semi-Arid	36°04' N	04°40' E	928	2000–2012	381,5
Setif	Semi-Arid	36°11' N	05°15' E	1033	2000–2012	402,69

2.2.2 MODIS time series data

In this study, the monthly MODIS NDVI extracted from the MOD13A1 version 6 product from the NASA Terra Vegetation Indices 16-Day L3 Global 500 m. The MODIS LST were retrieved from the MOD11A1 Version 6 product provides an average 8-day with a 1-km spatial resolution for the period from 2000 to 2012. The images were obtained via Google Earth Engine (GEE). The MOD13A1 and MOD11A1 data layers were used as provided without any additional geometric or radiometric corrections.

2.3 Methodology

For drought analysis over steppe regions, using data from the Google Earth Engine platform, we calculated standardized precipitation index (SPI), normalized difference vegetation index (NDVI) vegetation condition index (VCI), temperature condition index (TCI), and vegetation health index (VHI). SPI were computed at time interval of one month. The methodology for calculations of indices is described below in detail.

2.3.1 Standardized Precipitation Index (SPI)

Precipitation is one of the factors determines the severity and the persistence of drought. The SPI is The standardized precipitation index (SPI) method proposed by McKee et al. (1993, 1995) [9-10] and World Meteorological Organization WMO (2012) [11] was employed in this study to analyze the rainfall data by identifying dry and wet sequences and assessing the severity of drought. Meteorological drought category based on SPI shown in Table 2. In this study, the ground-based SPI indices were calculated from ground-observed precipitation by using the SPI Generator software provided by the National Drought Mitigation Centre of America (<https://drought.unl.edu/droughtmonitoring/SPI/SPIProgram.aspx>). The SPI Generator program fits the precipitation time series over different time scales (e.g. 1, 3, 6, or 12 months) to a Gamma function, and subsequently, the cumulative probability distribution of the gamma function is transformed into a standard normal distribution to yield the SPI [12]. The 1-month SPI received by the world climate organization as a reference of drought index to describe drought [13] was computed by using the following mathematical equation:

$$SPI = \frac{P_i - P_m}{\sigma} \quad (1)$$

where P_i is the seasonal precipitation, P_m is the long-term mean, and σ is the standard deviation of the long-term record. The drought categories defined by SPI values are listed below (Table 2).

Table 2. Classification of SPI [11]

Range of SPI	Drought Classes of SPI
$SPI < -2,0$	Extreme drought
$-2,0 < SPI \leq -1,5$	Severe drought
$-1,5 < SPI \leq -1,0$	Moderate drought
$-1,0 < SPI \leq 1,0$	Normal drought
$SPI > 1$	No drought

2.3.2 Normalized Difference Vegetation Index (NDVI)

The normalized difference vegetation index was used to identify and measure the vegetation dynamic. NDVI is a measure of surface reflectance and can be used to estimate the density of green on an area of land [14]. The normalized difference vegetation index (NDVI), (Equation 2) is one of the most widely used vegetation indexes, introduced by Rouse et al., (1974) [15] as an isolated vegetation index, with is the ratio of the difference between the near-

infrared band (NIR) and the red band (R) and the sum of these two bands. where NIR is reflectance in the near-infrared band and RED is reflectance in the visible red band.

$$NDVI = (NIR - RED) / (NIR + RED) \quad [16]$$

(2)

where

NIR = The Reflection in the near-infrared band and RED is reflectance in the visible red band.

RED = The Reflection of the light in Red band

In this formula, NIR is near infrared band, R is red band. Its domain is variable from -1 to +1. Negative values of NDVI, i.e. values approaching -1 correspond to deep water and positive values, i.e. +1 indicates very good and dense vegetation. NDVI provides an estimate of vegetation health and a means of monitoring changes in vegetation over time. NDVI values are categorized into five different (Table 3) classes based on the classification of NDVI results. The classification of NDVI values are performed for the indication of vegetated and non-vegetated areas and is further used to assess dry and wet areas. High values indicate a dense vegetation cover while low values indicate a lack of vegetation.

Table 3. Classification of NDVI [17]

Range of NDVI	Drought classes of NDVI
< 0	Extreme dry
0 - 0.2	Dry
0.2 - 0.4	Moderate
0.4 - 0.6	Wet
≥ 0.6	Extremely wet

2.3.3 Vegetation Condition Index (VCI)

VCI is calculated based on inputs like NDVI. VCI is a pixel-based analysis for finding vegetation conditions at a specific location of the pixel by considering the mean of the multi-annual variability and the minimum and maximum variability of the Vegetation Index.

$$VCI = 100 * (NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min}) \quad [18]$$

(3)

VCI was used to normalize the NDVI values from 2000 to 2011. $NDVI_{max}$ and $NDVI_{min}$ are the maximum and minimum values of each grid cell, respectively, calculated in terms of the corresponding pixels in the same month from the entire NDVI record (2000–2012). The range of the VCI is 0–100, which reflects changes in vegetation condition from the most unfavorable growth condition to the optimal growth condition. In months with extreme drought, the vegetation growth condition is poor and the VCI is close to 0. When the value of VCI is 50, it reflects vegetation.

2.3.4 Temperature Condition Index (TCI)

TCI is used to determine stress on vegetation caused by temperatures and excessive wetness. Conditions are estimated relative to the maximum and minimum temperatures and modified to reflect different vegetation responses to temperature. TCI varies from 0, for extremely unfavorable conditions to 100 for optimal conditions. TCI was developed based on LST observation from TIR remote sensing. as demonstrated in Equation (4).

$$TCI = 100 * (LST_{max} - LST) / (LST_{max} - LST_{min}) \quad [18]$$

(4)

where TCI was used to normalize the LST values from 2000 to 2012. LST_{max} and LST_{min} are the maximum and minimum values in each grid cell, considering the same month from 2000 to 2012. TCI ranges from 0 to 100. Values between 0 and 50 show drought condition whereas 50–100 indicate healthy vegetation as shown in Table 4 [19]. Consistently low TCI values over several consecutive time intervals may point to drought presence.

2.3.5 Vegetation Health Index (VHI)

The Vegetation Health Index (VHI) [20] is one of the many drought indices were developed and used to assess the vegetation response to droughts [21], especially used in arid, semi-arid, and sub-humid climatic regions [22]. In the present study, the monthly VHI for the growing season was computed from VCI and TCI, by using the following equation:

$$VHI = a \times VCI + (1 - a) \times TCI \quad [23] \quad (5)$$

where VHI = Vegetation Health Index, $a = 0.5$ (contribution of VCI and TCI), VCI = Vegetation Condition Index, TCI = Temperature Condition Index. The lower VHI value indicated that the high incidence of agricultural drought whereas a higher VHI value show wet or non-drought conditions (Table 4).

Table 4. Classification of the VCI, TCI and VHI [23-24]

Range of VCI, TCI and VHI	Drought Classes of VCI, TCI and VHI
< 10	Extreme Drought
< 20	Severe Drought
< 30	Moderate Drought
< 40	Mild Drought
> 40	No Drought

3. Results and Discussion

3.1 Spatiotemporal dynamics of 1-month SPI during the growing season

Spatiotemporal drought analysis by the 1-month SPI for the growing season indicates that drought occurring in the majority of the years during the period from 2000 to 2012 in the steppe regions (Figure 2). The severely dry (-1.5 to -1.99) condition of SPI class is mostly seen in southern tip of the study region and the moderate dry (-1,0 to -1,49) class is distributed over the southeastern and southwestern parts of the region from 2000 through 2012. The spatio-temporal changes of SPI interpret that most of the central, northern, and eastern parts of the study area are marked normally dry (-1,0 to 1,0) category. The distribution of rainfall is very irregular, the west and south regions is characterized by low rainfall with averages ranging from 286,57 mm in Nâama to 155,16 mm in Laghouat.

According to the SPI classification of WMO (2012) [11], the results showed that most of the stations in the western and southern in 2000, 2001, 2002, 2005, 2006, 2007 and 2009 were confronted with by severe to moderate droughts during the years, where parts of Nâama, El-Bayadh, Laghouat, and South of Djelfa are totally affected by drought. In addition, the results show that the regions of Tiaret, Setif, Bordj Bou Arreridj, Batna, Ain El Beida and Tebessa which experienced a humid period wet conditions with $SPI > 1,0$. When the remaining areas experienced near-normal conditions. Generally, precipitation is the most important factor in the occurrence of drought.

3.2 Spatiotemporal dynamics of NDVI during the growing season

MODIS NDVI time-series allow the monitoring of seasonal fluctuations in vegetation over a wide range of temporal scales over large areas [25]. It might also be employed as a robust measure for measuring soil surface moisture, allowing drought occurrences to be easily

detected. These NDVI values are distributed from $m - 1$ to $+1$ and have been categorized into 5 classes as extremely wet vegetation NDVI values range from (≥ 0.6), values range between (0.4-0.6) wet vegetation, moderate vegetation values range between (0.2-0.4), dry vegetation (0-0.2). Similarly, NDVI values less than 0 represent areas without vegetation cover shown in figure 3.

The spatio-temporal analysis of annual variation of the normalization difference vegetation index (NDVI) for the growing season for the period from 2000 to 2012 shows that the good vegetative cover was noticed in the years 2009 and 2010 (Figure 3). However, the NDVI values, during the year 2001 and 2002 were found far less than the remaining years.

In the year 2002, croplands were reflected with relatively low NDVI values whilst in the year 2009 the majority of the study area recorded with high positive NDVI values. During the same year, the entire southern, central, and western parts of the region recorded the NDVI value of > 0.4 and at the same time, the eastern and northern part of the study area was recorded with the NDVI value between > 0.6 . The analysis of NDVI of the growing season shows that the western and southern parts of the study area were characterized by poor vegetation cover in the majority of the years. While northern and eastern parts of the region exhibit relatively good vegetative cover. Obviously, there are great geographical differences of growing season NDVI in the steppe regions, which is closely associated with the diverse climate conditions. The northern part of the region shows relatively higher NDVI values, this could be attributed to the moderate forest cover in the region. Northern and eastern parts of the region also recorded the relatively higher NDVI values, which indicate moderate to dense vegetation.

3.3 Spatiotemporal dynamics of TCI during the growing season

The spatial distribution and variations of TCI values are presented in figure 4. The TCI indicates the hotness and coldness of land surface in the range of 0–100. Values less than 10 indicate extreme cases, while below 40 points out mild drought situations [19]. The results show that in the TCI also a lowest value can be spotted for 2000, 2001, 2002, and 2006 in most areas, whereas for 2008 high values were recorded for the studied region.

The TCI values will have indirect relation with the drought as the TCI values decreases, the degree of drought scale will become high. As like as the LST values the TCI values is also showing no drought class only in the parts of steppe regions. The spatiotemporal analysis of TCI represents that the high and extreme drought condition is mostly marked intense distribution throughout the study area during 2000 and 2001 whereas in 2006 and 2009 it is found high concentration over the northern portion. TCI is also following a smooth and almost uniform pattern spatially, save for certain changes in the years of the drought. It indicates that TCI has very small hand in contributing to droughts.

3.4 Spatiotemporal dynamics of VCI during the growing season

The temporal and spatial distribution of VCI is illustrated in figure 5 as drought and normal years. The VCI values are ranging from 0 to 100. Where values of VCI below 40 show extreme level of drought severity, while below 40 shows the beginning of mild drought [5]. The spatio-temporal analysis of VCI indicates that drought is a frequent phenomenon in the majority of the years during the period from 2000 to 2012 in the steppe regions. In the year 2002, the majority of the study area was under dry condition, Similar extreme drought conditions were also observed in the majority area of the region during the year 2001, followed by in 2000, 2003, 2004, 2005 and 2008, During the year 2000, extreme drought condition was experienced in the south western part of the study area, whereas, in the year 2001 and 2008 similar drought condition was noticed in the central, western, and eastern parts of the study area. The extreme drought condition was witnessed over the western and south parts of the study area during the

year 2003, 2004 and 2005. On the contrary, during the years 2009 and 2010, wet conditions were observed in the majority of the region.

3.5 Spatiotemporal dynamics of VHI during the growing season

Figure 6 shows the spatial and temporal development of annual vegetation health index of steppe for the period from 2000 to 2012. The analysis of VHI of the growing season shows that the entire southern, central and southwestern parts of the study area were characterized by poor vegetation cover in the majority of the years. While the densest vegetation is developing in northern and eastern parts of the study area. The eastern part of the region shows relatively higher VHI values (>40), this could be attributed to the moderate forest cover in the region and were not affected by drought, the south-west and south-east regions are exposed to severe ($VHI < 20$) and moderate ($VHI < 30$) droughts.

During 2000–2002 the region was affected by drought ($10 < VHI < 40$) owing to poor rainfall and water-stress. Moreover, during the year 2000, almost the entire portion of the study region except for the elevated regions in the southern portion are covered with high drought class. The 2002 drought was due to exceptionally low rainfall during. Since 2003. The area of vegetation degradation was distributed in the southwest part. It is concentrated in the south and central part of steppe regions, with highly intensified VHI class of extreme drought condition (<10). rather than extreme to high drought covers a large part of the servings. Contrary in 2009 highest values of VHI ($>40\%$) are recorded in most of the area, this might be due to good rainfall during the same period. The analysis of of VHI of the growing season helps to identify hot spots especially in severe vegetative stress regions over the northern, western, and central parts of the steppe regions. The precipitation variability, high temperatures, and topographical parameters like slope aspect also affects plant density and plant species diversity.

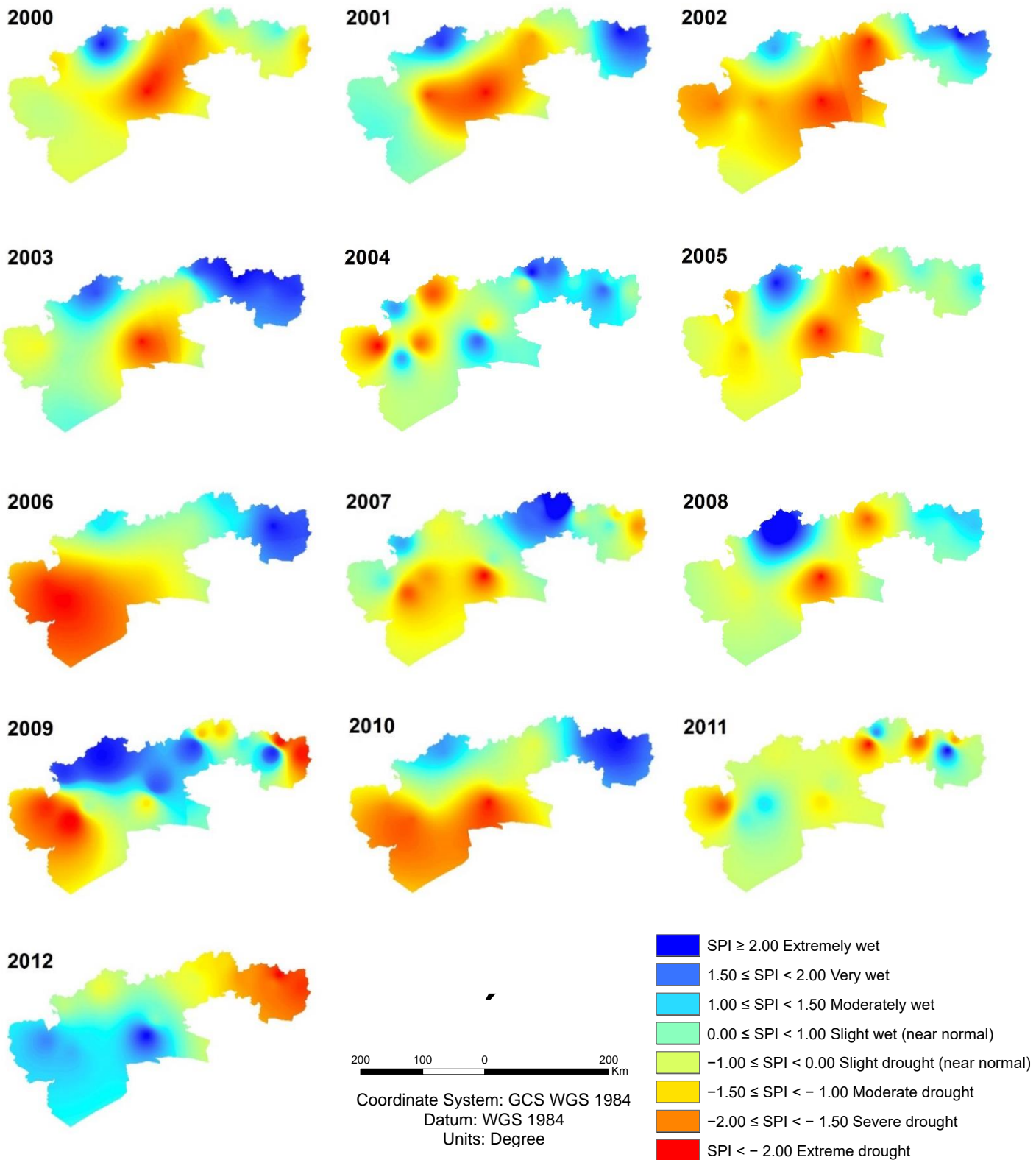


Figure 2. Spatiotemporal patterns of 1-month SPI of steppe during 2000–2012.

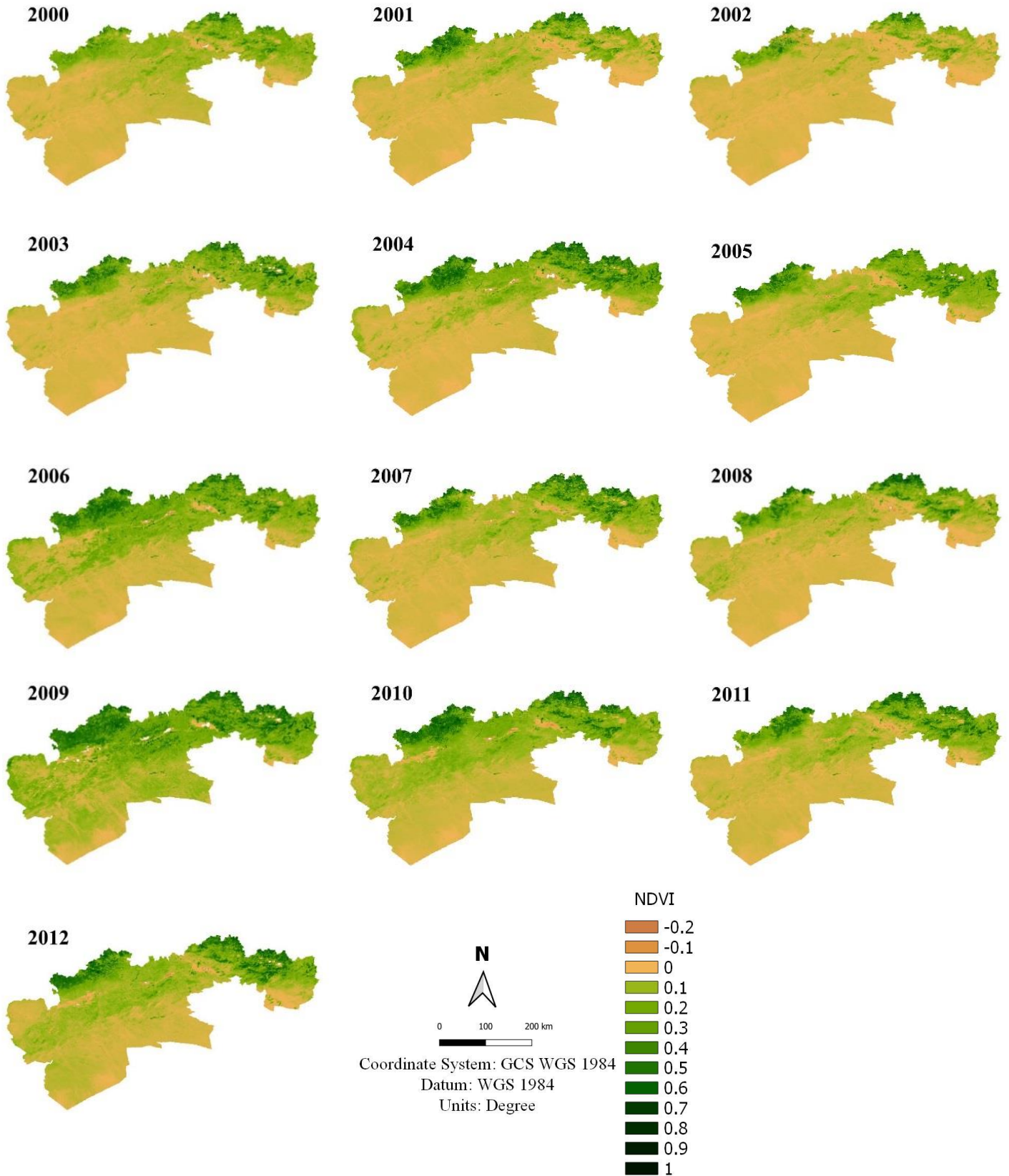


Figure 3. Annual Normalized Difference Vegetation Index in steppe from 2000 to 2012.

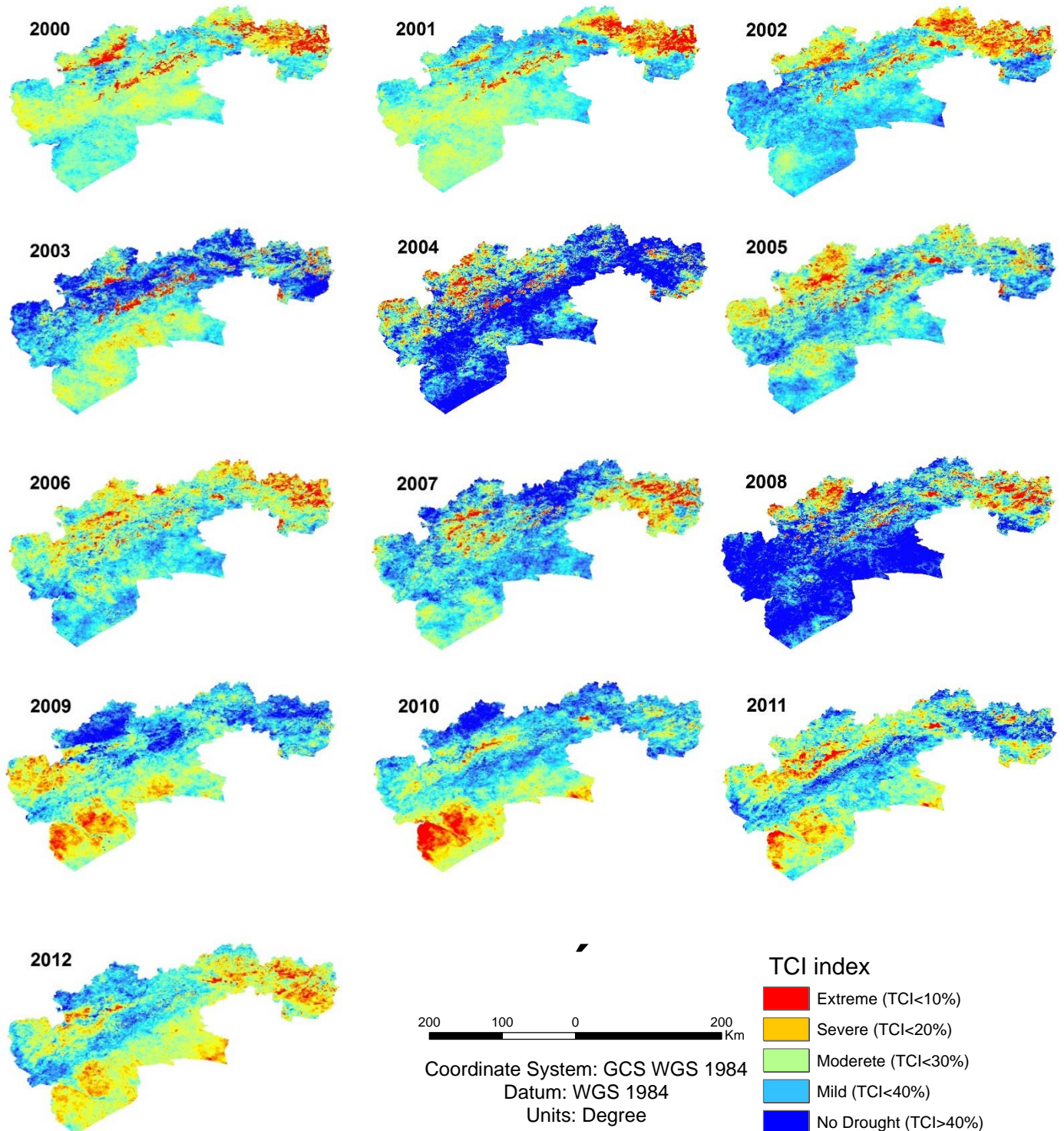


Figure 4. Annual Temperature Condition Index of steppe during 2000–2012.

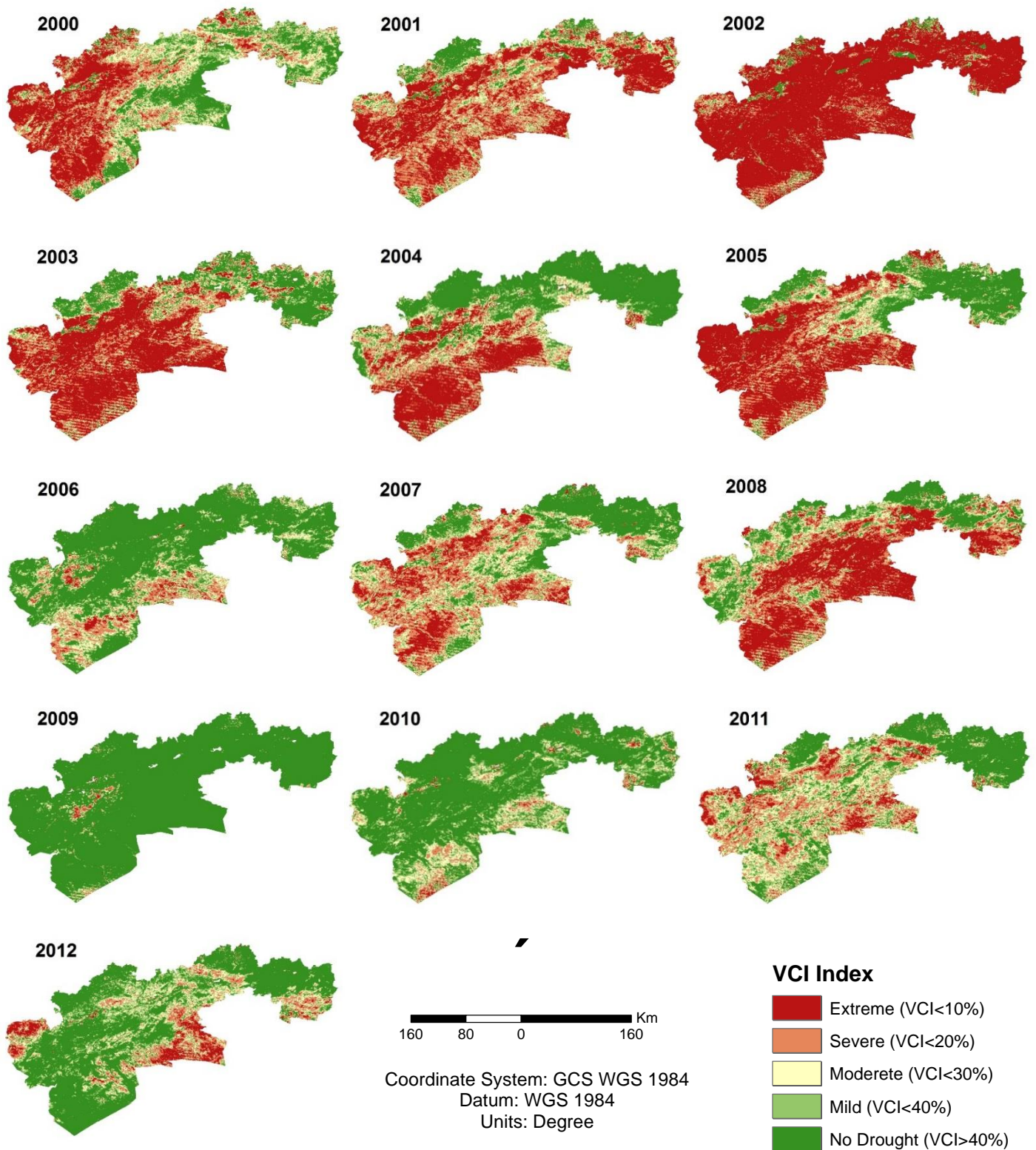


Figure 5. Annual Vegetation Condition Index of steppe during 2000–2012.

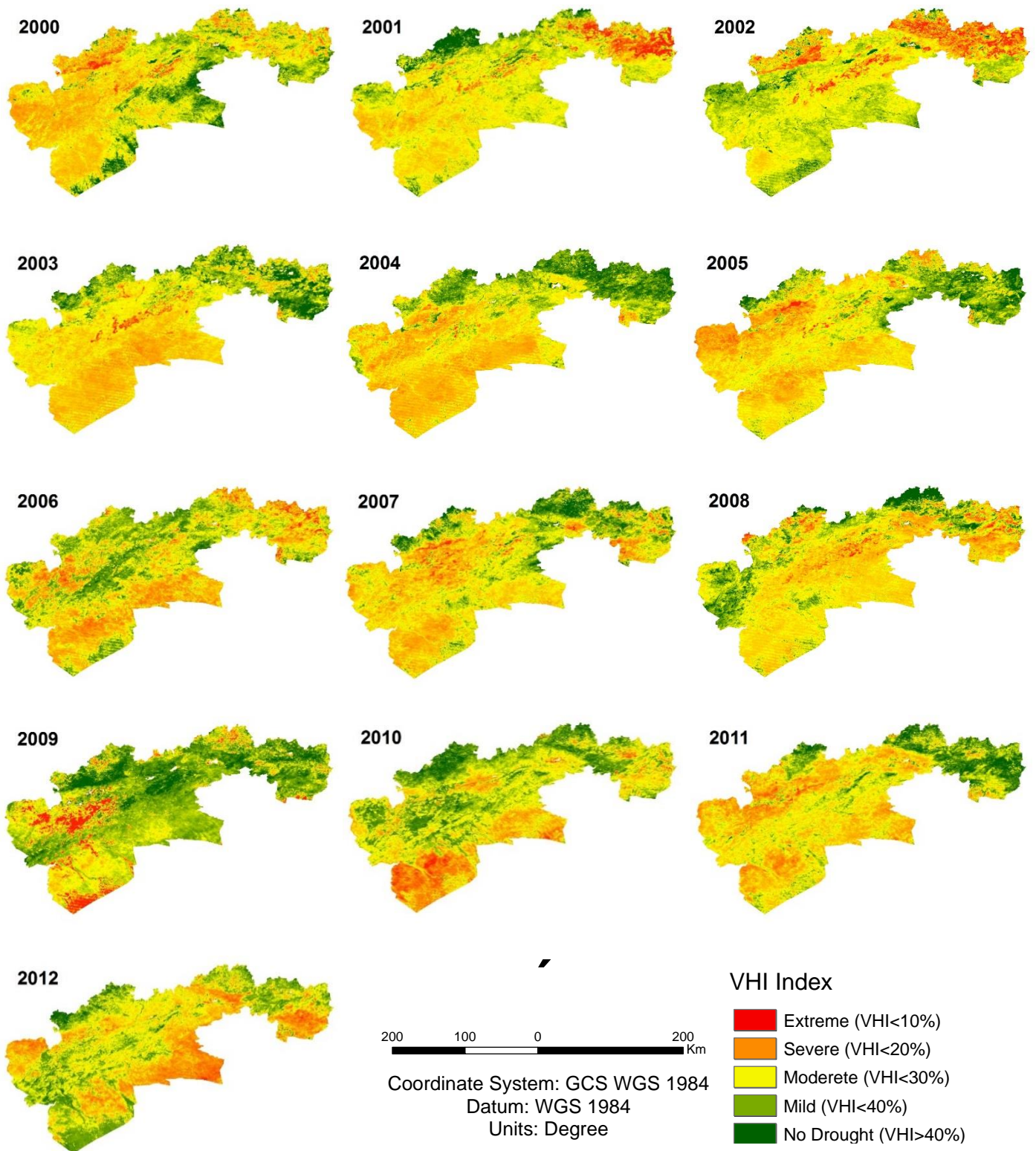
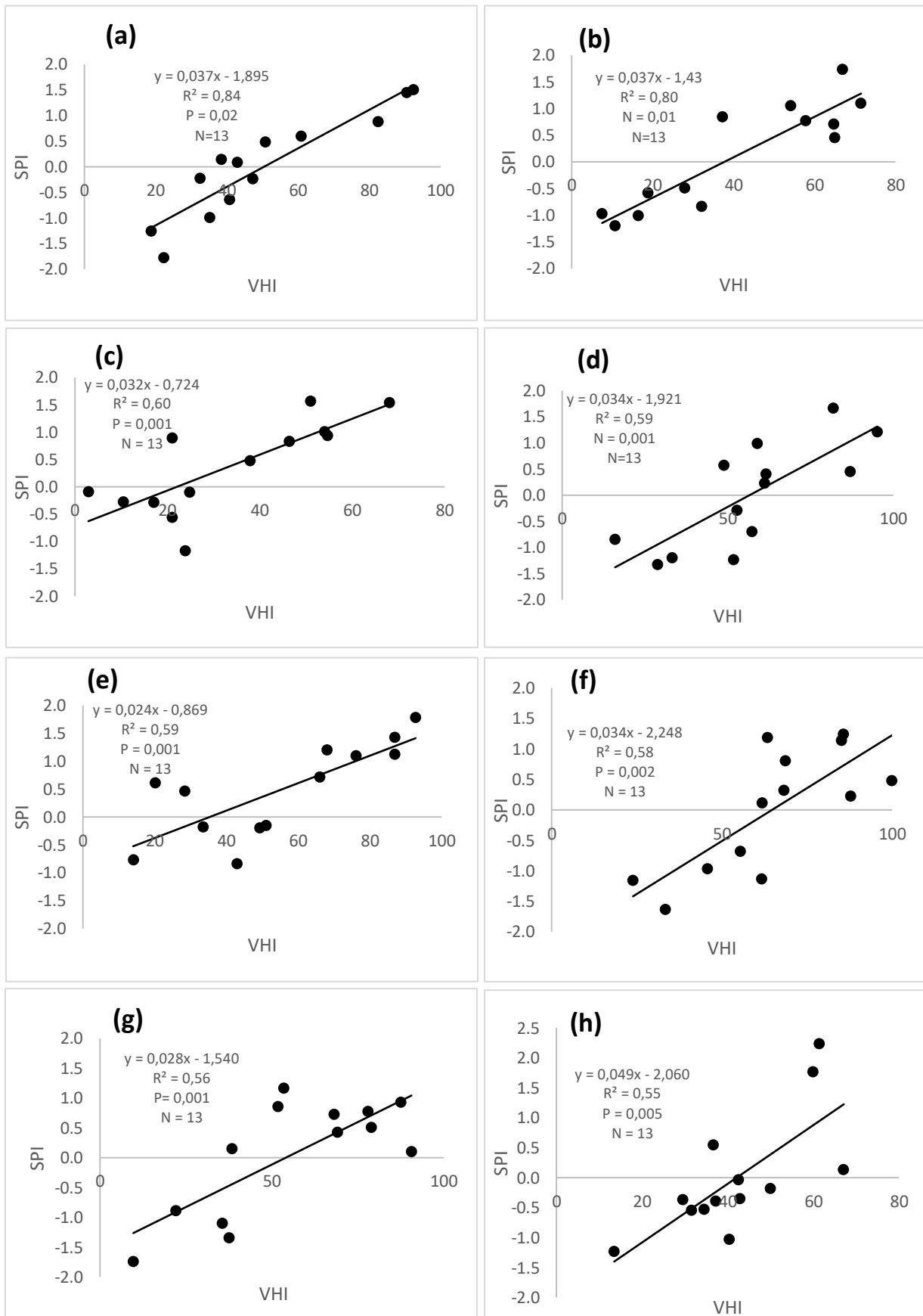


Figure 6. Annual Vegetation Health Index of steppe during 2000–2012.

3.6 Correlation between SPI and VHI

Many previous studies have indicated that VHI and SPI are correlated [26-29]. Figure 7 shows the relationship between VHI and SPI in the study area between 2000 and 2012. The results show that a positive high correlation was observed between VHI and SPI. Gidey et al., (2018) [22] were used drought indices to model the statistical relationships between meteorological and agricultural drought. They reported a significant and positive correlation between SPI and VHI at 3-month timescale in Raya and its environs, Northern Ethiopia. Yan et al., (2016) [30] found that the statistical relationship between the VHI and the SPI has strong spatiotemporal correlation during a drought period in Southwest China. Similar to the finding of this research, Ryu et al., (2019) [31] reported that a positive correlation between meteorological drought index and an agricultural drought index in Neighboring Counties of South and North Korea. However, this study has proven that there is a positive, relatively strong relationship between the SPI and the VHI ($R^2/P = 0,84/0,02$ to $R^2/P = 0,35/0,03$). A high regression result (R^2) was observed in the district of Tebessa ($R^2=0,84$) and El-Bayadh ($R^2=0,80$), while in the areas of Nâama, Batna and M'sila, the regression value was ($R^2 = 0,60$ and $R^2 = 0,59$). Similarly, in the other districts such as Khenchela, Saida, Tiaret, and Ain Beidha (Figure 7f–i), the relationships between VHI and SPI were ($R^2 = 0,58$, $R^2 = 0,56$, $R^2 = 0,55$ and $R^2 = 0,53$). On the contrary, a weak non-significant relationship was observed between VHI and SPI in other districts such as Djelfa, Setif, Bordj Bou Arreridj, Laghouat, and Mecheria, the relationship between SPI and VHI ranges from ($R^2/P = 0,35/0,03$ to $R^2/P = 0,49/0,01$) shown in figure 7j–n. These findings indicate that drought may be an important driver for vegetation degradation of the low density area of steppe regions. Because the source of water supply for this type of land use is the atmospheric precipitation, which has declined due to the occurrence of droughts. The same results have been reported by Hourizi et al., (2017) and Belala et al., (2018) [32-33]. Our results are also agree with the findings of Bouarfa et al., (2022) [34], who reported that the significant changes have occurred between the years 2002–2009 around the Djelfa, El Bayadh, and Ain Sefra regions (in the western part of our study area) due to the spatial-temporal extent of drought on steppe vegetation density and resilience. Moreover, our findings showed the existence of opposite correlations in different regions of the study area. As displayed, the positive correlation coefficients are mainly observed in the northern regions and the negative correlation coefficients are mainly observed in the southern regions of the study area. Different vegetation densities in different regions of the study area and their susceptibility to drought may be one of the main causes. In other words, differences in the sensitivity degree of different vegetation (e.g., dense and/or poor vegetation) to drought phenomenon may lead to opposite correlations in the study region.



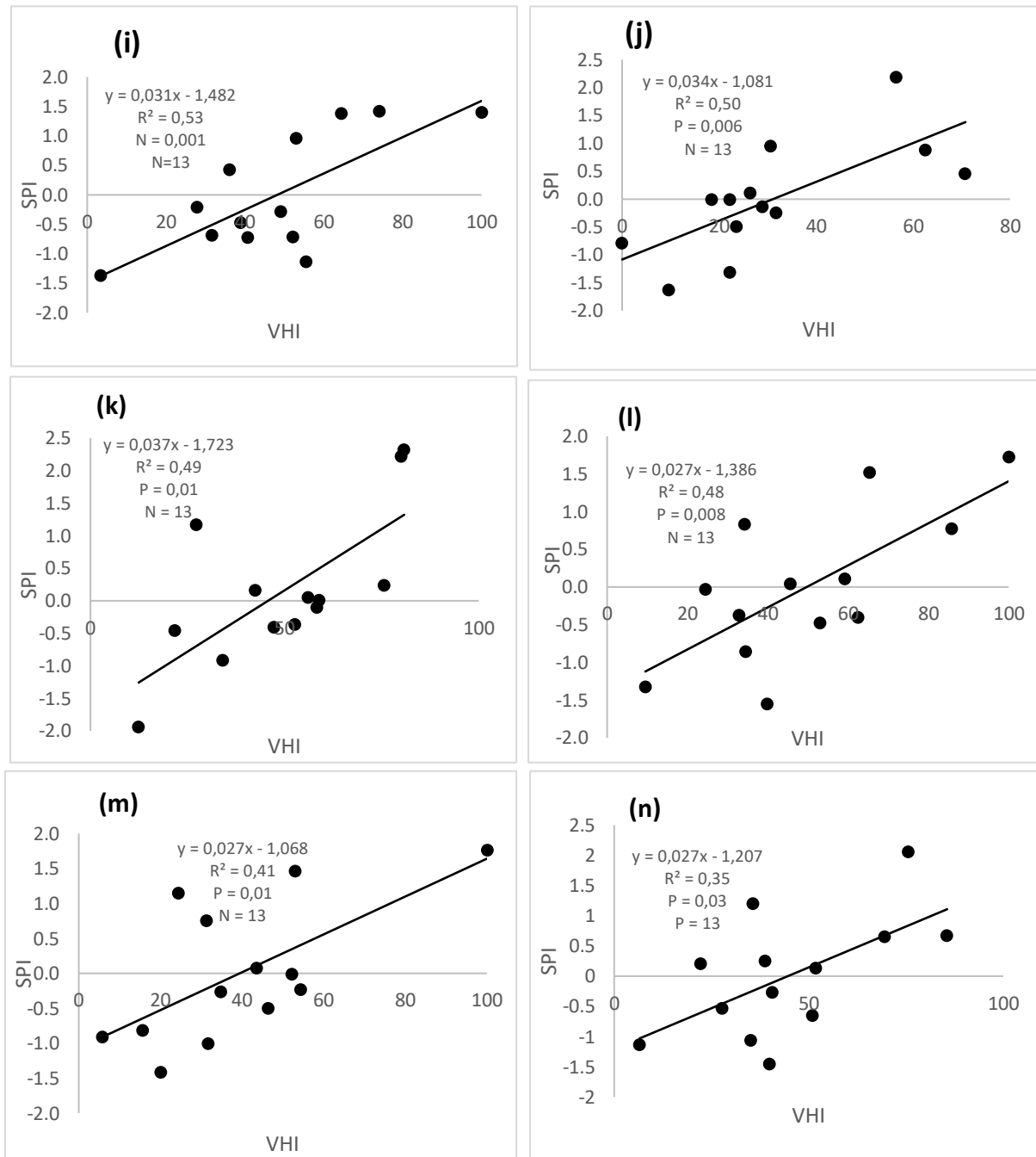


Figure 7. Correlation between VHI and SPI during 2000–2012.

4. Conclusion

In this study, five drought indices (SPI, NDVI, VCI, TCI, and VHI) were used for monitoring drought in the steppe regions for a study period from 2000 to 2012. The Standardized Precipitation Index (SPI) has been used to monitor meteorological drought. Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Vegetation Health Index (VHI) have been employed to assess vegetative drought in the terrain. Agricultural drought can be monitored using remotely sensed MODIS images. According to that, year 2000, 2001, 2002, 2003, 2004, 2005,

2007,2008 and 2011 can be identified as agricultural drought years for steppe regions. Severe agricultural drought prone areas are located in the west, south and central parts of steppe regions. In general, SPI and VHI clearly explain the relationship between meteorological drought and agricultural drought in steppe regions. The relationship between SPI and VHI is positive ($R^2 = 0,35$ to $R^2 = 0,84$) and statistically significant at ($p < 0,01$ and $p < 0,03$) across all districts of the study area. This relationship reveals that when rainfall increases, VHI also tends to increase. As a result, agricultural drought incidences significantly reduced. The VHI maps indicate that vegetation growth is although dependent on water supply through rainfall, it can withstand adverse meteorological and hydrological conditions for several seasons to maintain good vegetation health. In the steppe regions terrain, hydrological drought develops faster and recovers slower. On the contrary, vegetative drought is slow to begin but quicker to withdraw. Drought being a natural hazard refers to the adverse impacts on natural spheres and not to the causes for the impacts. Since precipitation is the primary cause for drought development, negative SPI anomalies do not always correspond to drought in reality, as it takes no account of impact. Therefore, SPI and VHI together presents better pictures and perceptions of drought, particularly in the semi-arid terrain of steppe regions.

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