



Monitoring and Investigating Drought Behavior Using Remote Sensing Data in Kermanshah Province

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Article Info	ABSTRACT
Article type: Research Article	Drought is one of the natural disasters whose long-term effects affect the economy and society. This phenomenon is considered a challenge in arid and semi-arid regions, including Iran. Nowadays, the use of remote sensing methods can help us in understanding the drought behavior of vegetation. In order to monitor and analyze the behavior of drought in Kermanshah province, the data of Sanjande Weathers products (VIIRS) and AVHRR data indexed by NOAA STAR were used. In this study, the Vegetation Health Index was used in the period of 1982-2021 in a seven-day format with a spatial resolution of 4 x 4 km. After extracting the data in the Kermanshah area, the vegetation drought trend was investigated on 65,387 cells using the Mann-Kendall test. The results showed that in the winter season, the trend of vegetation cover in the western areas of the province was decreasing and significant at the level of 0.05. While in the northern, central and eastern regions of the province, the trend is increasing and significant. In the spring and summer seasons, especially the months of June, July, August and September, which correspond to the dry months of the year, the size of the areas with a significant decreasing trend of vegetation cover has increased, while in the autumn season, with the beginning of the water year, the size of the areas with a decreasing trend has decreased.
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Introduction

Drought is a hydroclimatic phenomenon that occurs as a result of an unexpected reduction in precipitation, whereas aridity is an inherent and persistent characteristic of a region (Wilhite, 2000). Drought is one of the major environmental hazards, with adverse impacts on agriculture, ecosystems, the economy, and society (Zamanian et al., 2012; Alahacoon et al., 2021). Drought events vary in terms of their intensity, duration, and spatial extent. The magnitude of drought impacts is closely associated with the timing of onset, precipitation deficits, intensity, and duration of the event (Molavizadeh et al., 2016; Wilhite, 2000). Across the various definitions of drought, a common feature is a continuous and persistent period during which the amount of available water in a region decreases substantially (Mosaedi et al., 2008). The adverse effects of drought on human life have prompted the development of various approaches to mitigate its impacts. Drought can be examined from different perspectives, including meteorological, hydrological, agricultural, and socioeconomic drought (Wei et al., 2021; Kloos et al., 2021; Dhawale and Paul, 2018). Given that Iran is predominantly located in arid and semi-arid regions, it is highly susceptible to drought, which can develop into a major environmental and socioeconomic crisis (Moradi et al., 2011). One effective approach for monitoring drought is the use of remote sensing techniques and satellite imagery. Satellite observations provide broad spatial coverage, suitable spatial and temporal resolution, and relatively low costs compared with conventional methods, making them an effective tool for monitoring and assessing drought conditions (Lessel et al., 2016).

Vegetation drought occurs when soil moisture is insufficient during the plant growing season. This condition can result from various factors, including inadequate precipitation, high temperatures, and excessive evapotranspiration (Li et al., 2017). Precipitation and evapotranspiration are the two primary factors controlling the development and persistence of dry conditions in vegetation worldwide (Lloyd-Hughes and Saunders, 2002). The Vegetation Health Index (VHI) is one of the widely used satellite-based indices for drought monitoring (Li et al., 2020; Bento et al., 2018). The VHI was developed to detect vegetation drought and consists of two main components: the Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI). This index has the advantage of effectively monitoring vegetation drought (Hu et al., 2020). The VHI accounts for local biophysical conditions, such as soil and topography, as well as climatic conditions, and can be used for near-real-time monitoring of vegetation drought across different agricultural and climatic regions (Bhuiyan et al., 2006). The contributions of land surface temperature (LST) and the Normalized Difference Vegetation Index (NDVI) to vegetation health depend on geographic location, climatic conditions, and vegetation type (Bento et al., 2020). Several studies have investigated the VHI, which can be broadly classified into three groups according to the satellite platform used. Some studies have employed Landsat imagery to investigate the VHI (Sholihah et al., 2016; Shamsoddini and Raval, 2018; Saurabh et al., 2021; Mohanasundaram et al., 2023). Other studies have used the Moderate Resolution Imaging Spectroradiometer (MODIS) to investigate the VHI (Rahul et al., 2013; Kirana et al., 2020; Annisa et al., 2020; Ekundayo et al., 2021). Other research has examined drought conditions using the Advanced Very High Resolution Radiometer (AVHRR) and NOAA satellite data (Karamushka et al., 2022; Lima et al., 2023; Bhukya et al., 2023). Hamzeh et al. (2017) investigated the spatiotemporal characteristics of drought in Markazi Province, Iran, using vegetation indices. Their results indicated that the study area was generally characterized by moderate to low vegetation cover and that the climatic conditions of the region showed greater agreement with the vegetation-index results at the seasonal scale. Soltani et al. (2018) used

Landsat satellite imagery to monitor drought and vegetation health in Kermanshah Province, Iran. Their findings demonstrated that Landsat imagery and derived indices can be effectively used for drought monitoring. Bento et al. (2018) employed the Standardized Precipitation Evapotranspiration Index (SPEI) and Pearson correlation analysis to evaluate the contributions of the Temperature Condition Index (TCI) and Vegetation Condition Index (VCI) to the Vegetation Health Index (VHI) in arid regions. They found that both TCI and VCI were important predictors of VHI in arid environments, although TCI showed a stronger contribution than VCI. Dhawale and Paul (2018) demonstrated that VCI is more sensitive than TCI during wet seasons. This is because VCI is derived from the Normalized Difference Vegetation Index (NDVI), which generally exhibits higher values during wet seasons. In contrast, TCI is derived from land surface temperature (LST), which tends to be lower under wet conditions. Their results also indicated that TCI is more sensitive than VCI under high-temperature conditions. This is because TCI is based on LST, which generally increases under high-temperature conditions, whereas VCI is derived from NDVI, which tends to decline under such conditions (Dhawale and Paul, 2018). Han et al. (2020) investigated the spatiotemporal characteristics of drought in the Changbai Mountains of China during 2001–2018 using the Precipitation Condition Index (PCI), VCI, VHI, Standardized Drought Condition Index (SDCI), and Temperature Vegetation Dryness Index (TVDI). Their results revealed substantial spatiotemporal variations in drought conditions across the study area. Approximately 20% of the study area exhibited significant increasing or decreasing trends in drought conditions. Zhao et al. (2021) investigated the spatiotemporal characteristics of drought in northwestern China during 2003–2020 using the Standardized Precipitation Index (SPI), VCI, TCI, VHI, and Normalized Vegetation Supply Water Index (NVSWI). Their results showed that the frequency, duration, and intensity of drought exhibited decreasing trends over the study period. Navabi et al. (2021) assessed agricultural drought in the Lake Urmia Basin using VCI, VHI, and TCI. Their findings indicated that remote-sensing-based indices provided good accuracy in characterizing the spatial and temporal distribution of agricultural drought. Zeng et al. (2023) compared the Standardized Precipitation Evapotranspiration Index (SPEI) and self-calibrating Palmer Drought Severity Index (sc-PDSI) as reference drought indices for evaluating the contributions of TCI and VCI to VHI. They found that sc-PDSI performed better than SPEI as a predictor of drought conditions in arid regions.

Kermanshah Province is one of the western provinces of Iran and is geographically located in an arid and semi-arid region. Owing to its distinctive climatic conditions, the province has long been susceptible to drought. Since field-based assessment of the entire province is not feasible, remote sensing techniques, such as the Vegetation Health Index (VHI), were employed as an appropriate tool for assessing and monitoring vegetation health. As highlighted in the literature review, numerous studies have investigated the Vegetation Health Index for drought assessment. The aim of this study was to investigate the spatiotemporal characteristics of drought and its changes over the past four decades in Kermanshah Province. To this end, data from the Visible Infrared Imaging Radiometer Suite (VIIRS), as well as Advanced Very High Resolution Radiometer (AVHRR) data available through the NOAA STAR database¹, were used. Previous studies have demonstrated that the VHI can effectively characterize drought conditions. Therefore, the application of this index may contribute to improved drought monitoring and management in Kermanshah Province.

Materials and Methods

Study Area

¹ National Oceanic and Atmospheric Administration (NOAA) Center for Satellite Applications and Research (STAR)

Kermanshah Province, with Kermanshah city as its capital, covers an area of approximately 24,640 km² and ranks as the seventeenth-largest province in Iran by area. The province accounts for approximately 1.5% of Iran's total land area. Geographically, Kermanshah Province extends from 45°20'39" E to 48°01'58" E in longitude and from 33°37'08" N to 35°17'08" N in latitude. The province is located in western Iran and shares borders with Kurdistan Province to the north, Ilam Province to the south, Hamadan Province to the east, and Iraq to the west. The mean elevation of the province is approximately 1,200 m above sea level.

Data Used

In the first step of this study, gridded Vegetation Health Index (VHI) data were obtained from the NOAA STAR database in Network Common Data Form (NetCDF) format. The data are provided at 7-day intervals, resulting in approximately 52 images per year, with a spatial resolution of 4 × 4 km. The VHI data matrix has dimensions of 10,000 × 3,636 and provides global coverage. A total of 65,387 pixels within Kermanshah Province were identified for the study, providing adequate spatial coverage of the province. The study period for the vegetation health index data extended from 1982 to 2021. In the next step, MATLAB was used to process the gridded data. Statistical analyses were subsequently performed, and the resulting data were then mapped and analyzed using ArcGIS.

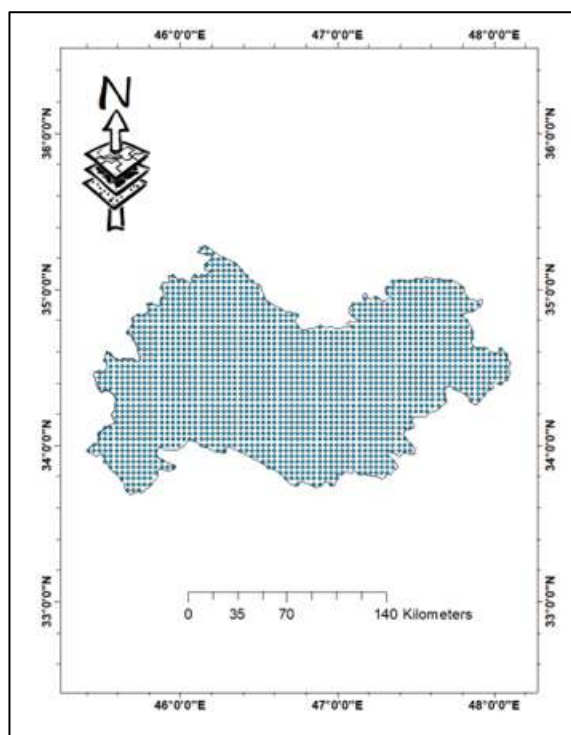


Figure 2. Spatial distribution of grid cells in Kermanshah Province

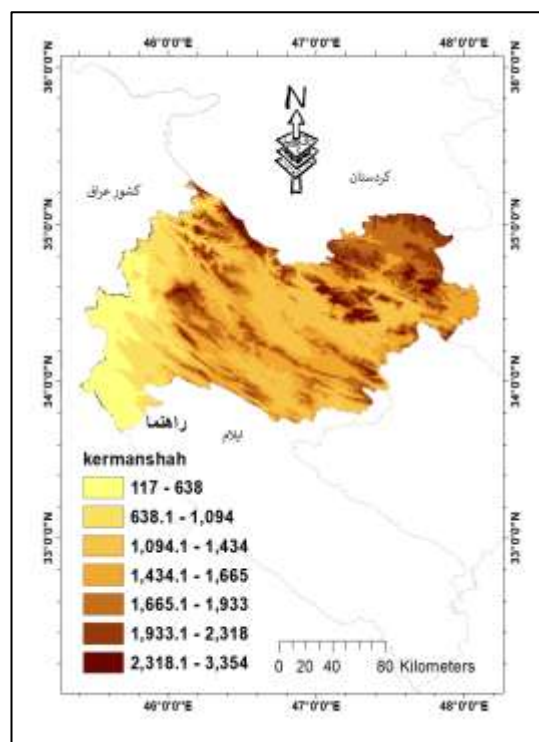


Figure 1. Geographical location of Kermanshah Province

Methods Used

Analysis of the Vegetation Health Index (VHI)

Kogan(1997) proposed the Vegetation Health Index (VHI) to assess vegetation stress in relation to water availability and temperature. The VHI is a composite index that integrates the Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI), with the aim of incorporating vegetation moisture conditions and land surface temperature into a

single measure. The VHI has been widely used for various applications, including the detection and assessment of drought severity ([Amalo et al., 2017](#); [Kogan and Zhu, 2001](#)). The VHI is calculated using the following equation:

$$VHI = (0.5 * VCI) + (0.5 * TCI) \quad \text{Eq. (1)}$$

$$VCI = \frac{(NDVI_i - NDVI_{min})}{NDVI_{max} - NDVI_{min}} * 100 \quad \text{Eq. (2)}$$

$$TCI = \frac{(LST_{max} - LST_i)}{LST_{max} - LST_{min}} * 100 \quad \text{Eq. (3)}$$

In the above equation, VCI indicates vegetation condition, while TCI represents temperature condition. LSTmax denotes the maximum land surface temperature, LSTmin the minimum land surface temperature, and LSTi the land surface temperature on the i-th day. NDVIi represents the Normalized Difference Vegetation Index on the i-th day. NDVImin and NDVImax in the above equations correspond to the minimum and maximum Normalized Difference Vegetation Index, respectively ([Zuhro et al., 2020](#)). VHI represents overall vegetation health and is used for drought identification ([Karnieli et al., 2010](#)).

Table 1: Drought classification based on the VHI index

VHI Value (%)	Drought Category
< 10	Extreme drought
$10 \leq VHI < 20$	Severe drought
$20 \leq VHI < 30$	Moderate drought
$30 \leq VHI < 40$	Mild drought
> 40	No drought (Normal)

Mann-Kendall (M-K) Non-parametric Test:

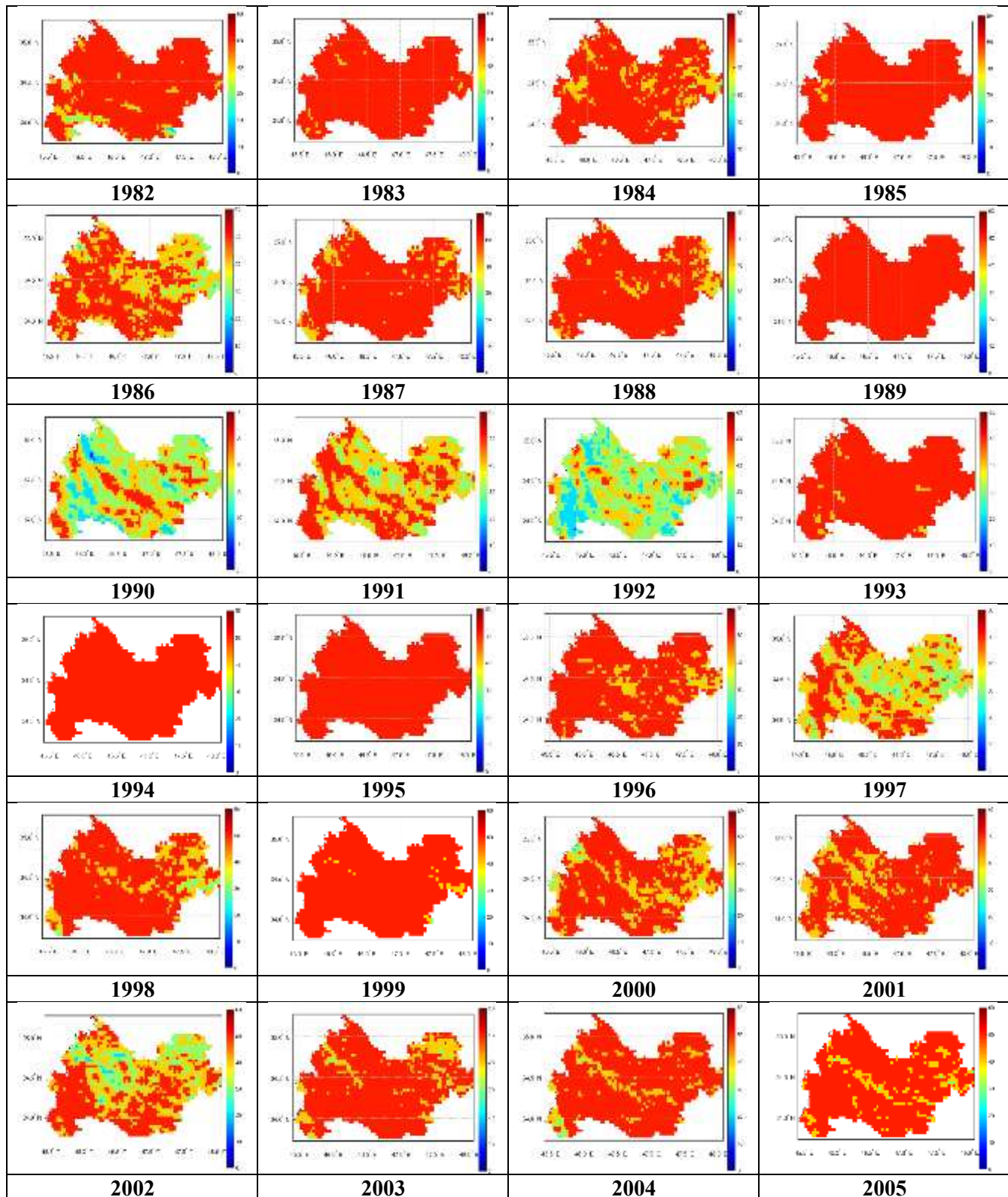
This test was originally proposed by [Mann](#) (1945) and later developed by [Kendall](#) (1975), and its application is recommended by the World Meteorological Organization (WMO). One of the key strengths of this method is its suitability for time series that do not follow a specific statistical distribution. Another advantage is its low sensitivity to extreme values, which are often observed in certain time series. This test is widely used to examine the randomness of data (i.e., absence of trend) versus the presence of a trend in hydrological and meteorological time series ([Partal and Kahya, 2006](#)). In the present study, the non-parametric Mann-Kendall test, along with Sen's slope estimator, was employed to analyze trends in monthly satellite-derived data. The Mann-Kendall test has been extensively applied to quantify the significance of trends in climatological time series ([Da Silva et al., 2015](#)). Furthermore, an additional benefit of this test is its robustness against outliers and extreme values commonly found in some time series datasets ([Ebrahimi and Kordavani, 2014](#)).

Results and Discussion

Annual Analysis of the VHI Index in Kermanshah Province:

Figure 3 illustrates the annual status of the Vegetation Health Index (VHI) in Kermanshah Province over the period from 1982 to 2021. In this figure, red areas indicate non-drought conditions, while a shift toward blue hues signifies an intensification of drought severity. The spatial distribution reveals that the most extensive vegetation drought occurred during the years 1990, 1991, 1992, 1997, 2002, 2009, 2013, 2014, 2016, and 2018. In other years, scattered patches with values below 30—indicative of mild drought—are observable.

Overall, the figures clearly demonstrate that both the spatial extent and the severity of vegetation drought have notably increased in recent decades.



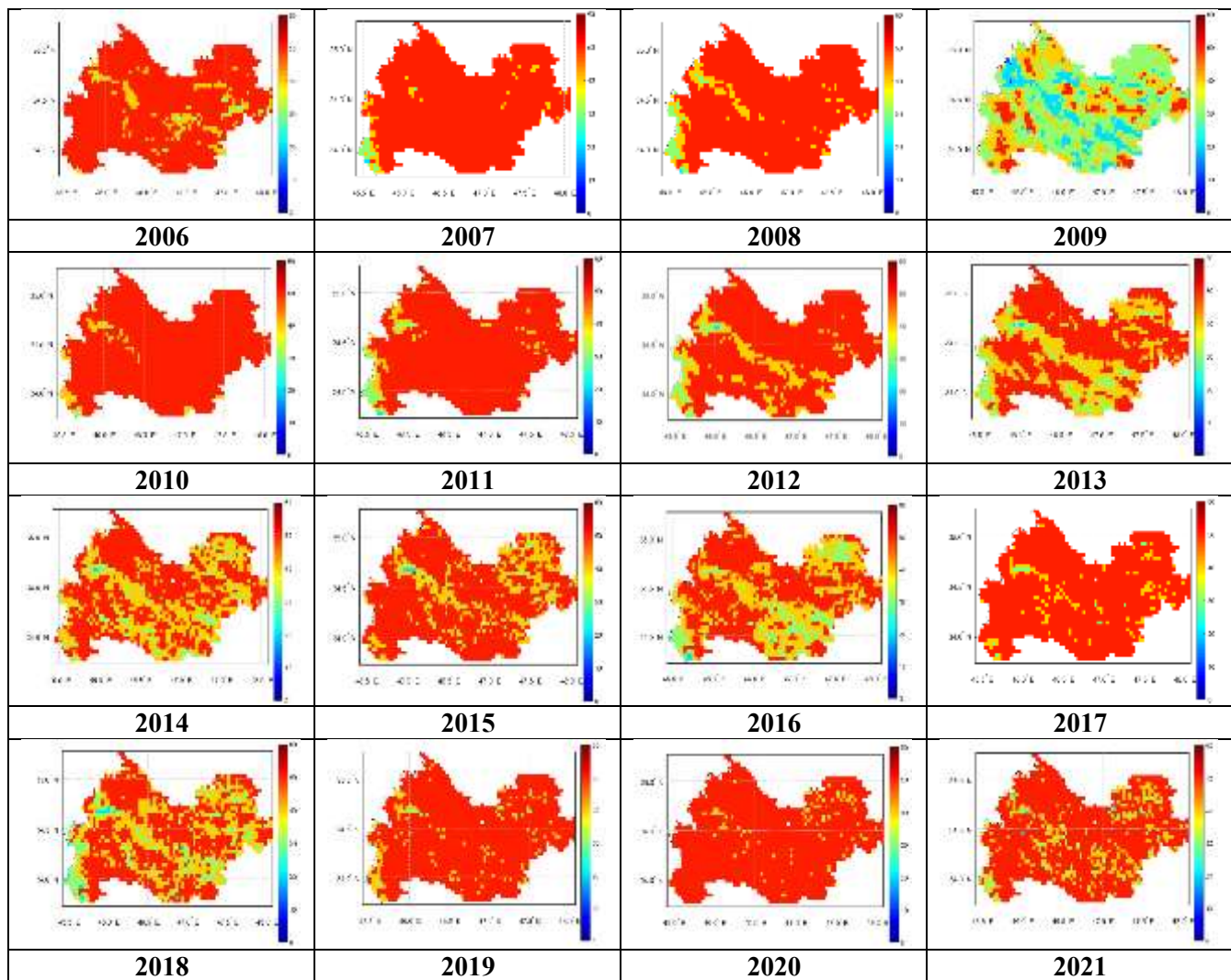


Figure 3. Map of VHI index coefficients across different years in Kermanshah Province

Winter Analysis of the VHI Index

The long-term mean of the Vegetation Health Index (VHI) for the winter season is illustrated in Figure 4. As shown in the figure, during January, parts of the western and central regions of the province exhibit VHI values ranging from 20 to 30 and 30 to 40, indicating moderate and mild drought conditions, respectively. In this month, the cities of Kermanshah, Harsin, Sahneh, Kangavar, Ravansar, Javanrud, Dalahu, Islamabad-e Gharb, and Gilan-e Gharb experience moderate to mild drought. In February, the spatial extent and severity of drought across the province have increased, predominantly affecting the central, eastern, and partially northwestern regions. Conversely, in March—the final month of winter—drought intensity and coverage in the central parts of the province have diminished compared to the preceding months. Instead, moderate to mild drought is primarily observed in the eastern regions, corresponding to the cities of Kangavar, Sonqor, and Sahneh. Overall, vegetation health conditions are more favorable in the western part of the province during winter. This can be attributed to the influx of precipitation systems from the west, as well as the presence of topographic features that enhance moisture retention in these areas. On average, approximately 65% of Kermanshah Province experiences vegetation drought during the winter season.

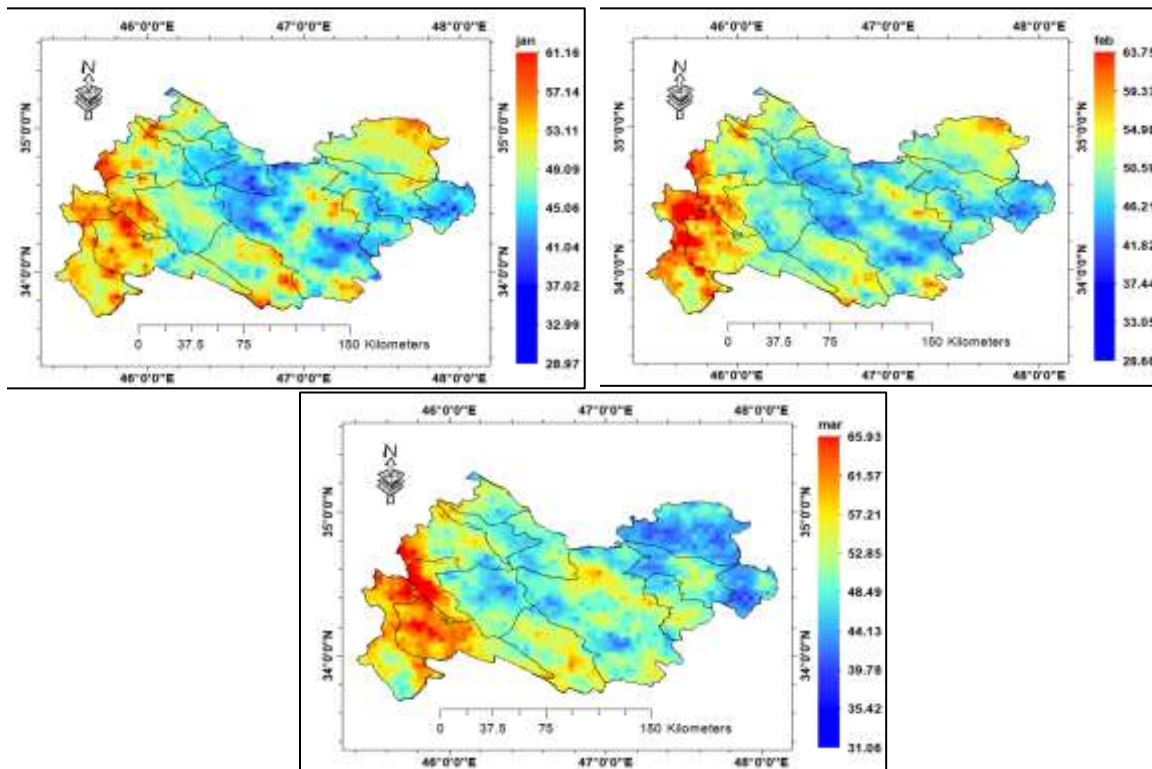
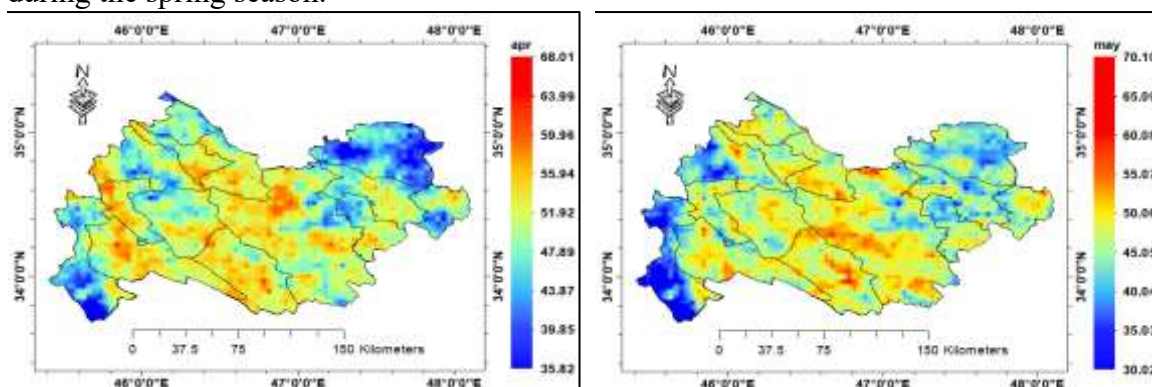


Figure 4. Long-term average map of the VHI index during winter in Kermanshah Province

Spring Analysis of the VHI Index

Figure 5 illustrates the spatial distribution of the VHI across Kermanshah Province during the spring season. During this season, the western and northeastern regions of the province generally experience mild to moderate drought conditions. In April, mild drought is confined to specific areas in the northeast (including Sonqor County) and the southwestern border regions with Iraq, particularly around the Sumar area. According to the VHI classification table, these areas exhibit index values between 30 and 40, which corresponds to mild drought. Meanwhile, the remaining parts of the province remain in a non-drought state. In May, mild drought is observed only in the southwestern part of the province, specifically in Qasr-e Shirin County, while the vast majority of the province continues to experience non-drought conditions. In July, there is a slight expansion of drought conditions along the western border regions of the province. Specifically, mild to moderate drought is observed in the western parts of Salas-e Babajani, Sarpol-e Zahab, and Qasr-e Shirin counties, whereas other areas maintain favorable conditions with no signs of drought. On average, approximately 35% of Kermanshah Province's total area experiences vegetation drought during the spring season.



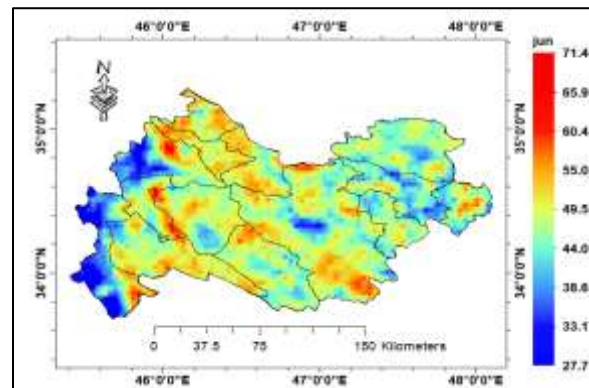


Figure 5. Long-term mean map of the VHI during the spring season in Kermanshah Province.

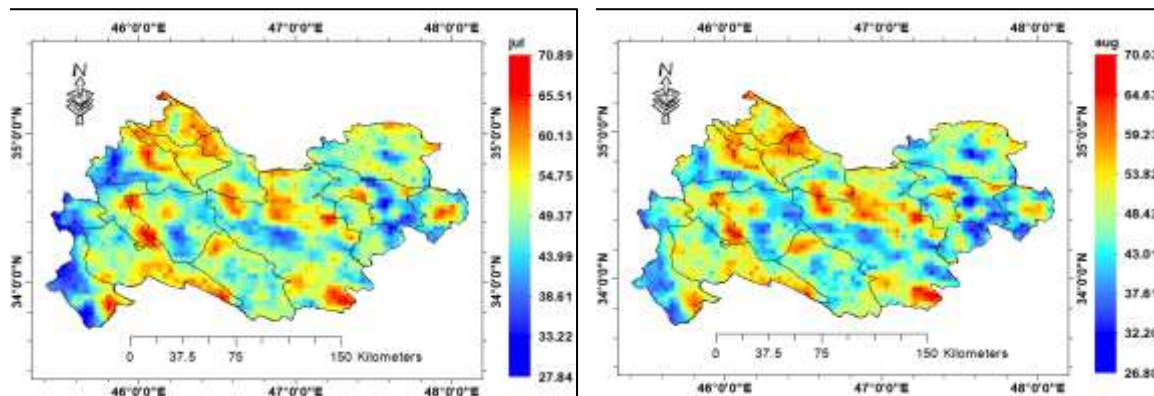
Summer Analysis of the VHI Index:

Figure [5] illustrates the spatial distribution of the VHI during the summer season in Kermanshah Province. In July, moderate to mild drought is observed across the central, eastern, and western parts of the province. Based on the VHI classification table, areas with index values between 20 and 30 indicate moderate drought, while values between 30 and 40 represent mild drought. Consequently, the northwestern and certain northern regions, which exhibit values exceeding 40, are classified as non-drought areas.

In August, a pattern similar to the previous month is observed, with moderate to mild drought affecting the central, western, eastern, and southern regions. Meanwhile, parts of the northwestern and, to some extent, central areas of the province remain in favorable, non-drought conditions.

By September, moderate to mild drought persists in the eastern, central, and western parts of the province. Only specific areas in the northwest, namely Paveh, Javanrud, and Ravansar counties, maintain favorable conditions and are free from drought.

Overall, during the summer season, approximately 45% of Kermanshah Province's total area experiences vegetation drought based on the Vegetation Health Index.



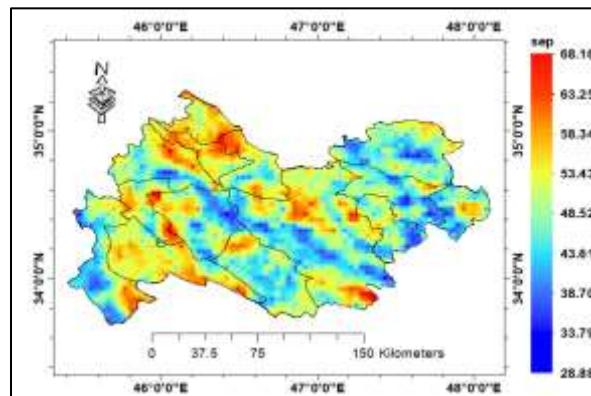


Figure 6. Map of long-term average VHI during summer in Kermanshah Province

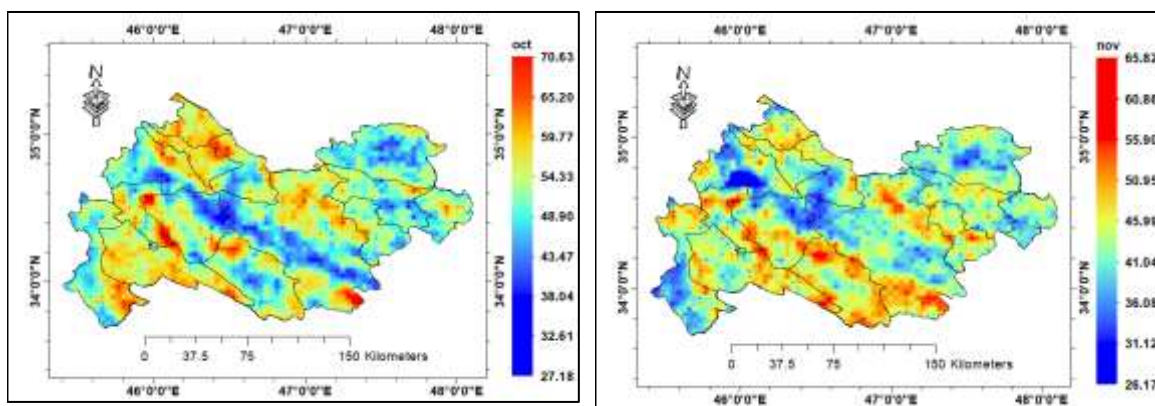
Autumn Analysis of the VHI Index

Figure 7 illustrates the spatial distribution of the VHI across Kermanshah Province during the autumn season. In October, moderate to mild drought conditions are observed in the central, eastern, and western regions of the province, corresponding to Kermanshah, Dalahu, Sarpol-e Zahab, Sonqor, Kangavar, Qasr-e Shirin, and Harsin counties.

In November, contrary to the previous month, both the intensity and spatial extent of drought have decreased across various parts of the province. Moderate to mild drought is confined to specific areas in the central, northeastern, and western regions, primarily affecting Kermanshah, Sonqor, Kangavar, and Sarpol-e Zahab counties, as well as portions of Dalahu and Salas-e Babajani. Consequently, November exhibits the most favorable non-drought conditions among the autumn months.

By December, mild drought prevails in the central, eastern, northwestern, and southwestern regions. Notably, the northwestern areas—which typically experience non-drought conditions—are affected by mild drought during this month.

Overall, the analysis reveals that the majority of pixels in autumn fall within the 20–30 range (moderate drought) and the 30–40 range (mild drought). On average, approximately 54% of Kermanshah Province's total area experiences vegetation drought during the autumn season.



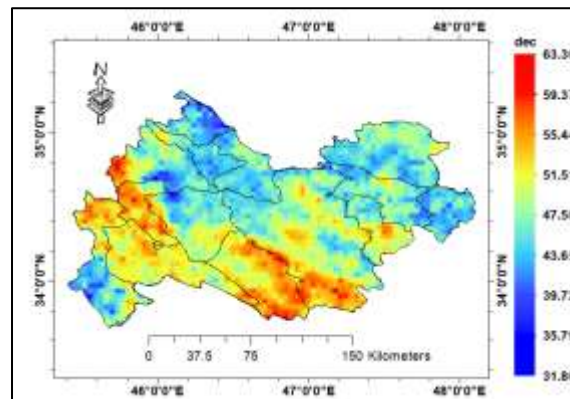


Figure 7. Long-term mean map of the Vegetation Health Index (VHI) during autumn in Kermanshah Province.

Trend Analysis of Vegetation Dynamics in Kermanshah Province

Trend Analysis of VHI Changes in Winter

The results of the Mann-Kendall test, based on vegetation condition and health indices for January in Kermanshah Province at a 95% confidence level, indicate that the western regions—specifically Salas-e Babajani and Sarpol-e Zahab counties—exhibit a significant trend. Since the Z-statistic is less than -1.96 at this confidence level, the trend is decreasing; consequently, vegetation conditions in these areas are unfavorable (Figure 8). In other words, drought severity has increased. Conversely, the eastern, northwestern, and parts of the central regions show a significant increasing trend, reflecting improved vegetation health and reduced drought impact during this month.

In February, results reveal that beyond the western regions, parts of the southwestern, southern, and northeastern areas—corresponding to Qasr-e Shirin, Islamabad-e Gharb, Sumar, and Sonqor counties—also exhibit a significant decreasing trend. This decline signals adverse drought impacts on vegetation. Meanwhile, other areas, particularly the eastern and central regions, demonstrate a significant increasing trend in vegetation health at the 95% confidence level.

By March, only the western and portions of the southern regions maintain a significant decreasing trend at the 95% confidence level. Overall, winter trends suggest that northern areas—with higher latitudes and greater precipitation—show increasing vegetation trends with no observable drought. However, western regions such as Sumar, due to their proximity to Iraqi deserts and lower latitude resulting in reduced rainfall, exhibit a significant decreasing trend. Previous studies have confirmed declining precipitation in the province's western zones (Mohammadi, 2010; Abakhti Grossi, 2012), with Abakhti Grossi (2012) specifically attributing lower rainfall in western Kermanshah to its lower latitude. During this season, approximately 40% of the province experiences a decreasing trend in vegetation health index, indicative of drought conditions (Figure 8).

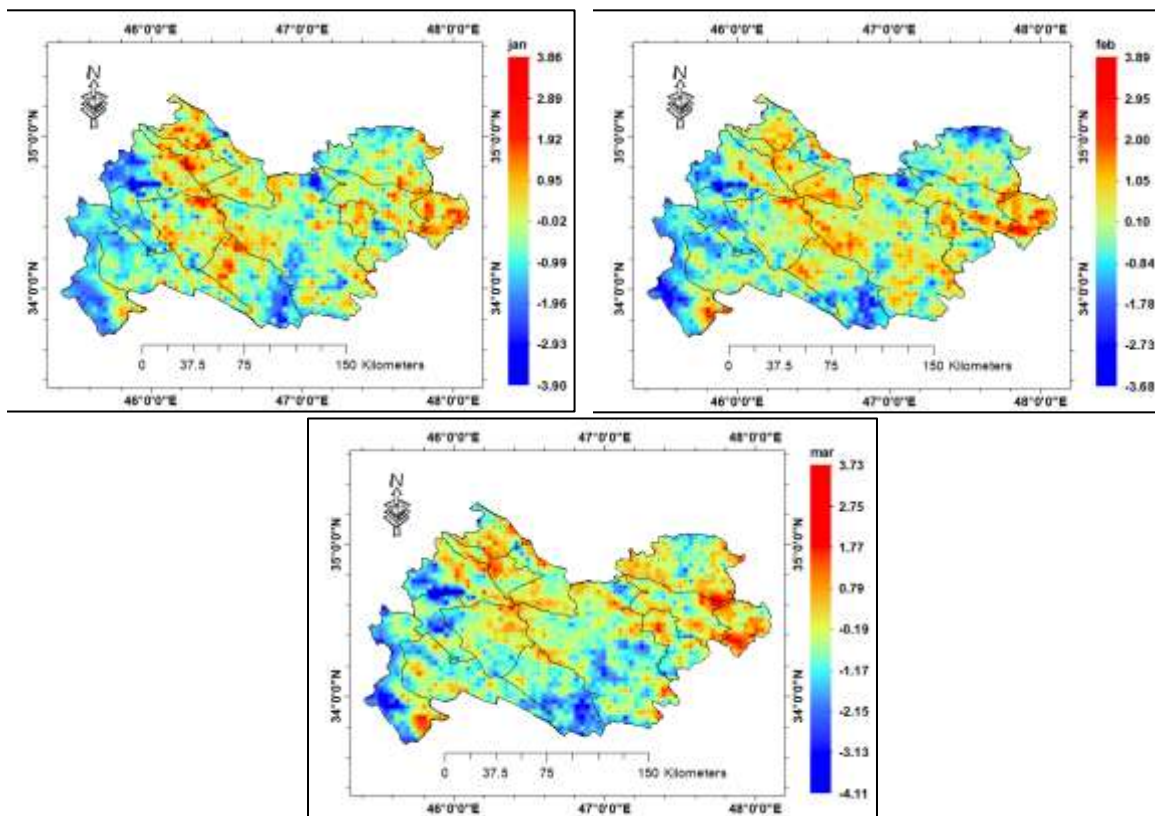


Figure 8. Spatial trend patterns of the VHI index during winter based on Mann-Kendall coefficients in Kermanshah Province

Analysis of VHI Trend Changes During Spring

Figure 9 presents the Mann-Kendall test results based on the Vegetation Health Index in Kermanshah Province during April. Among the cities in Kermanshah Province, Qasr-e Shirin, Sarpol-e Zahab, and Salas-e Babajani exhibited significant decreasing trends. In contrast, eastern, northern, and parts of southern and central regions of the province showed significant increasing trends, indicating favorable vegetation conditions in these areas. However, results for May revealed decreasing and significant trends in western regions, indicating declining vegetation cover in these areas. During the same period, eastern, northern, and parts of central and southern regions of the province exhibited significant increasing trends. Results for June indicate that the decreasing trend in vegetation cover during this month was more pronounced compared to previous months. In June, western, southern, and central regions of the province, corresponding to the cities of Kermanshah, Eslamabad-e Gharb, Sarpol-e Zahab, Salas-e Babajani, and Qasr-e Shirin, showed significant decreasing trends; however, during the same month, only parts of eastern, northern, and central regions exhibited increasing trends, with some areas showing statistically significant increases. During the first two months of spring, reduced precipitation was the primary reason for vegetation decline in western Kermanshah. As previous studies have demonstrated, this season experienced lower precipitation and increased temperatures in these regions. However, by the final month of this season, areas experiencing decreasing trends and affected by drought had expanded, such that moving from northwest toward west, southwest, and south of the province, vegetation cover diminished. This appears to be attributed to reduced spring precipitation during this period (Lotfi, 2015). Overall, approximately 45% of the province's area exhibited decreasing vegetation trends during this season. In other words, based on the Vegetation Health Index,

it can be stated that drought impacts affected vegetation cover across approximately 45% of the province's extent.

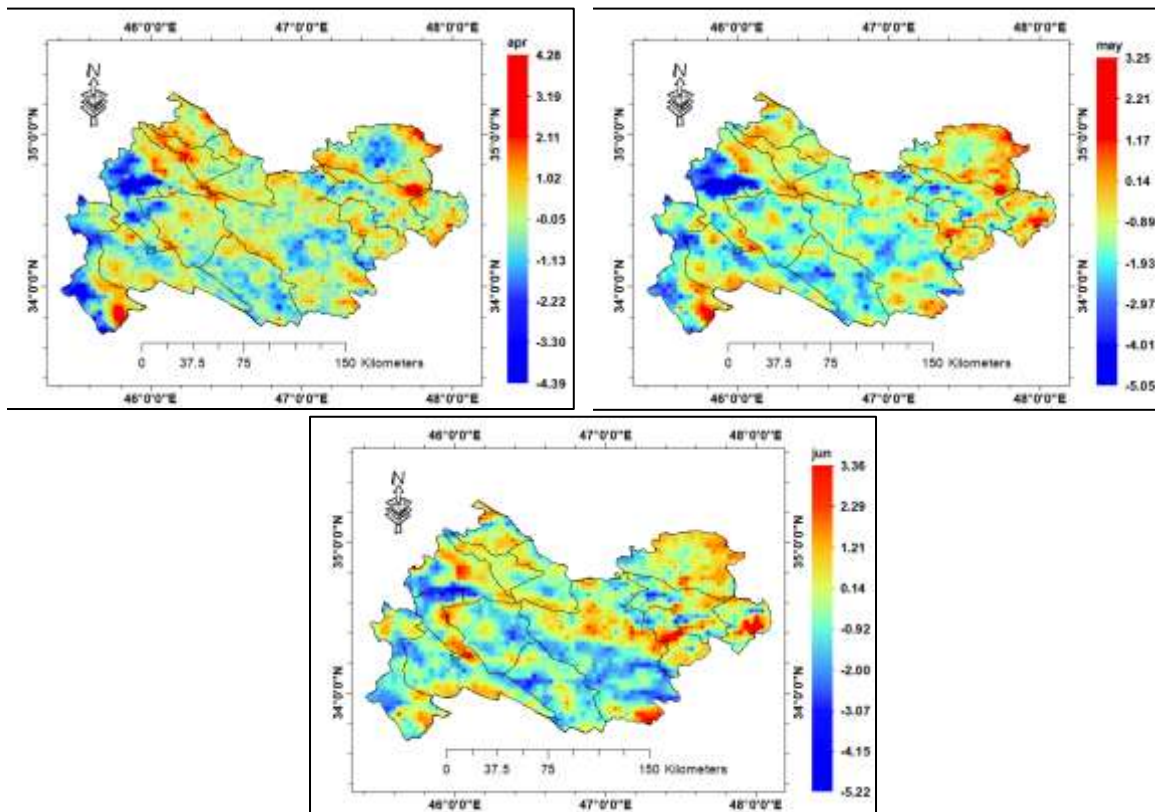


Figure 9. Spatial trend patterns of the VHI index during spring based on Mann-Kendall coefficients in Kermanshah Province.

Analysis of VHI Trend Changes During Summer

The results of the monthly Mann-Kendall test across all studied stations in Kermanshah Province revealed that, in July, the spatial extent of areas experiencing unfavorable vegetation conditions had expanded (Figure 10). Statistically significant decreasing trends were observed in the western and southern regions of the province. During this month, the area exhibiting increasing trends diminished, with significant increasing trends restricted to only certain parts of the central and northern regions. In other words, the majority of Kermanshah Province was impacted by drought-induced vegetation stress during this month. The results for August indicated that, in addition to the western and southern regions, significant decreasing trends also emerged in parts of the northern areas. Conversely, during this month, the central regions and parts of the eastern province exhibited significant increasing trends, indicating relatively better vegetation conditions compared to other areas of the province. In the final month of summer, September, results similarly demonstrated significant decreasing trends in the southern, western, and northeastern regions, reflecting unfavorable vegetation conditions in these areas. However, during this same month, significant increasing trends were observed in parts of the central, northern, and specific sections of the western and eastern regions.

Since the subtropical high-pressure system dominates the province during the summer months (July, August, and September), precipitation is virtually absent across most of the region. Previous studies conducted in summer have shown that as the season transitions from rainy to rainless months, vegetation cover and greenness across various land uses which rely

on precipitation for their moisture requirements—progressively decline. It appears that climatic elements, particularly temperature and precipitation, significantly influenced vegetation during this season. The observed vegetation decline is primarily attributed to the lack of effective precipitation during this time of year (Mohammadi, 2010). Furthermore, the establishment of high-pressure systems during summer leads to arid conditions across most of Iran. Alijani, et al., (2019) demonstrated that temperatures exceeding the 95th percentile became widespread across most meteorological stations and effectively normalized; consequently, this temperature increase aligns with the decreasing trend of this index during the summer season. During this season, approximately 60% of the province's area exhibited a decreasing trend in vegetation cover. This decreasing trend in the vegetation index is indicative of intensifying drought conditions within the province.

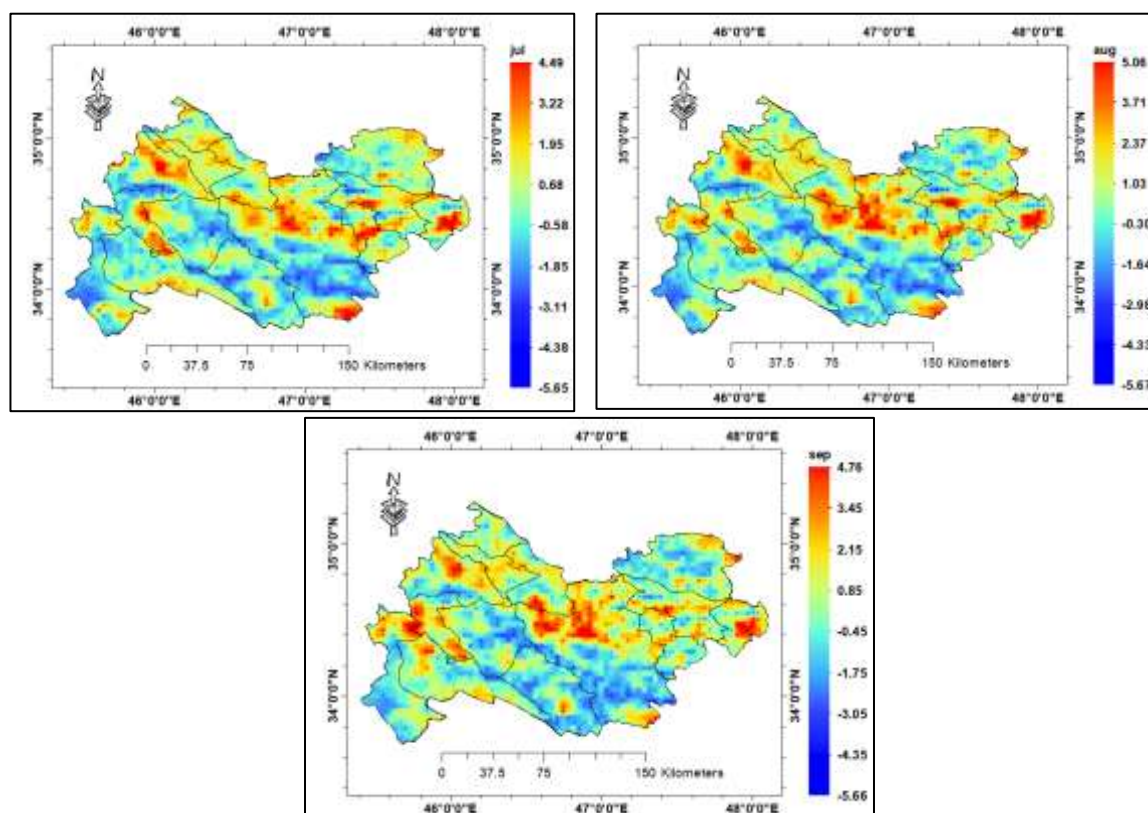


Figure 10. Spatial trend patterns of the VHI index during autumn based on Mann-Kendall coefficients in Kermanshah Province.

Analysis of VHI Trend Changes During Autumn

The results of the Mann-Kendall test, applied to the Vegetation Health Index (VHI) at a monthly scale and a 95% confidence level across stations in Kermanshah Province, revealed distinct spatial patterns for October. Statistically significant decreasing trends were observed in the southern, northeastern, and parts of the western regions, indicating unfavorable vegetation conditions in these areas. Conversely, during this same period, significant increasing trends in vegetation cover were detected across the western, central, northern, and eastern parts of the province. Results for November indicated a broader expansion of positive trends compared to the previous month. Significant decreasing trends were confined to specific sections of the western, southern, northern, and northeastern regions—primarily corresponding to the cities of Kermanshah, Sonqor, Sarpol-e Zahab, Salas-e Babajani, Javanrud, and Paveh. By December, significant

decreasing trends persisted in the western regions and parts of the northern and southern areas; meanwhile, the eastern, central, and northern regions continued to exhibit significant increasing trends in vegetation cover. Previous studies on autumn dynamics indicate that in October, the retreat of high-pressure systems and the incursion of westerly winds lead to increased precipitation in the western parts of the province. Given the direct correlation between rainfall and vegetation health, this enhanced precipitation appears to be the primary driver of improved vegetation conditions in the west during October. Furthermore, in November and December, the further intensification of westerly winds and the passage of rain-bearing air masses have contributed to sustained increases in vegetation cover (Mohammadi, 2010; Abakhti Grossi, 2012). Overall, approximately 43% of the province exhibited a decreasing trend in the vegetation index during the autumn season. This declining trend underscores the persistent impact of drought on the region's ecological health (Figure 11).

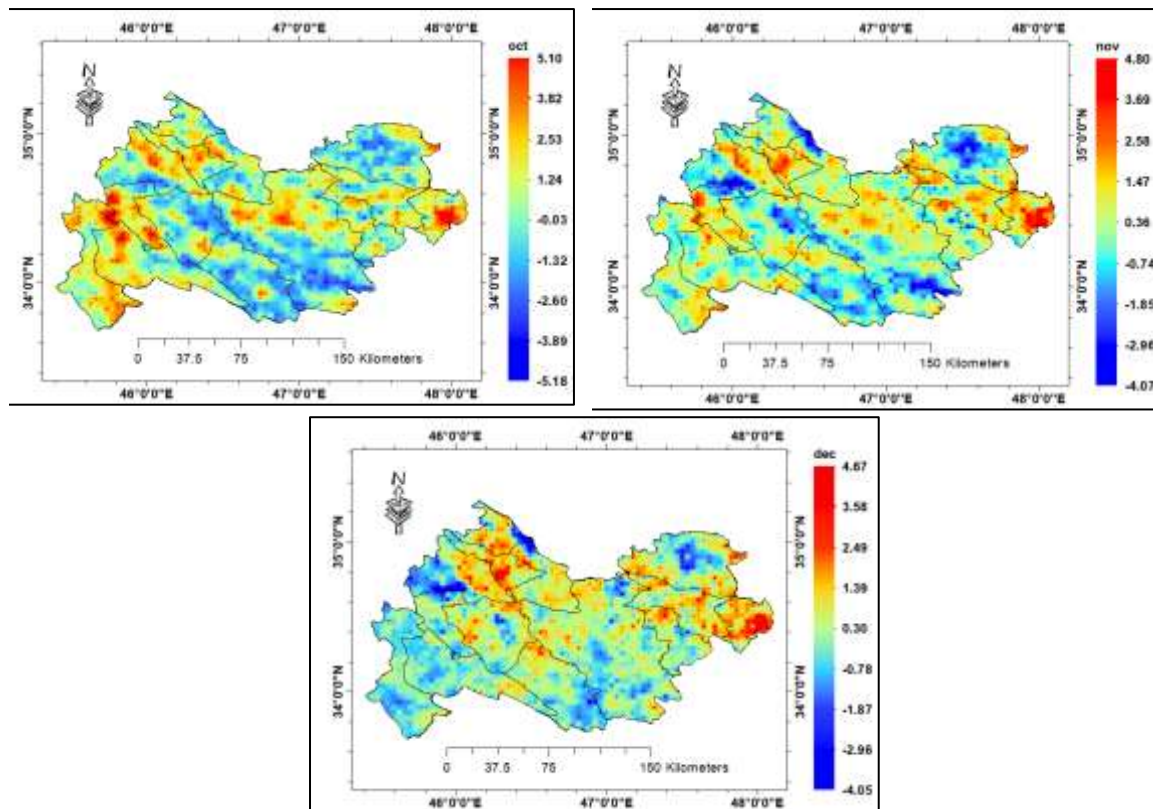


Figure 11. Spatial trend patterns of the VHI index during autumn based on Mann-Kendall coefficients in Kermanshah Province.

Conclusion

In this study, data from the Visible Infrared Imaging Radiometer Suite (VIIRS) and Advanced Very High Resolution Radiometer (AVHRR) products, available through the NOAA STAR platform, were utilized to monitor and analyze drought dynamics in Kermanshah Province. The Vegetation Health Index (VHI) was applied over the 1982–2021 period at a weekly temporal resolution and a 4×4 km spatial resolution. Annual assessments of this index revealed that the most extensive vegetation drought conditions occurred in the years 1990, 1991, 1992, 1997, 2002, 2009, 2013, 2014, 2016, and 2018. Furthermore, the spatial extent of these drought conditions has notably expanded in recent years. Seasonal spatial analysis of the VHI indicated that, on average, 65%, 35%, 45%, and 54% of the

province's area experienced mild to moderate drought during winter, spring, summer, and autumn, respectively. Monthly evaluations demonstrated that during January, February, and March, the western regions of Kermanshah Province exhibited more favorable conditions compared to other areas. This suggests that topographical features and the incursion of western weather systems have played a significant role. In April, May, and June, the western and northeastern regions of the province experienced mild to moderate drought conditions. During June, July, August, September, November, and December, the majority of the province was subjected to mild to moderate drought.

Trend analysis of the VHI in Kermanshah Province revealed statistically significant decreasing trends across extensive areas during specific seasons and months, highlighting the adverse impacts of drought on vegetation. Specifically, significant decreasing trends were observed in the western and border regions during winter. In the final month of spring, in addition to the western areas, decreasing vegetation trends extended to the southern and central parts of the province. This declining trend signifies a deterioration in vegetation health, indicating that drought impacts on vegetation have become pronounced in these areas. Spatial maps for the summer season indicated an expansion in the extent of drought-affected areas, with this season exhibiting the most severe decreasing trends. During autumn, the decreasing trends gradually diminished, particularly starting from the western regions, which can be attributed to increased precipitation and the arrival of rain-bearing synoptic systems. The assessment of drought in the province using the VHI confirmed the efficacy and reliability of this index for drought monitoring applications. The occurrence of mild to moderate drought was most severe during the summer months (June through September). Overall, the spatial extent of decreasing trends in the vegetation drought index across Kermanshah Province was approximately 40%, 35%, 60%, and 43% during winter, spring, summer, and autumn, respectively. One of the limitations of this study is the spatial resolution of the satellite data. Had a finer spatial resolution been available, it would have been possible to specifically assess and monitor irrigated agricultural lands.

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