Journal of Emergy, Life Cycle and System Analysis in Agriculture

Journal homepage: jelsa.uoz.ac.ir

Estimating the relative performance of rainfed crops using Fraction of Absorbed Photosynthetically Active Radiation index, land, and field data

Mehran Zand *[a], Morteza Miri [a], Mohamad Reza Kousari [a], Jahangir Porhemmat [a], Mahnaz Rahmati [b], Ali Akbar Noroozi[a], Ebrahim Karimi Sangchini [c], Kiyanfar Payamani [c]

[a] Soil Conservation and Watershed Management Research Institute (SCWMRI), Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran

[b] Department of Agricultural and Horticultural Research, Lorestan Agricultural and Natural Resources Research and Education Center, Agricultural Resaerch, Education and Extension Organization (AREEO), Khorramabad, Iran

[c] Soil Conservation and Watershed Management Research Department, Lorestan Agricultural and Natural Resources Research and Education Center, AREEO, Khorramabad, Iran

ARTICLE INFO

Article history:
Received: 12 October 2022
Accepted: 1 January 2023
Available online: 11 January 2023

Keywords:
Absorbed photosynthetically active radiation index
Crop yield
Drought
Lorestan province

ABSTRACT

In most regions of Iran, including the province of Lorestan, the majority of agricultural activities are conducted in the open air. Climate risks have a significant impact on agricultural productivity. Drought and its effects are among the most significant natural threats to the agriculture industry in that area. The purpose of this study is to investigate the effects of drought on the yield of rain-fed crops in Aleshtar county, Lorestan province. To achieve this goal, a combination of field methods, remote sensing, and statistical methods was employed. During ground surveys, data required for laboratory operations (direct method) and measurements using AccuPAR and MODIS sensor images were collected (indirect method). In addition, precipitation data from synoptic stations in the province of Lorestan over the course of 27 years (1991-2017) were utilized to calculate the drought and its impact on yield. According to the calculated drought indices, in the province of Lorestan and the county of Aleshtar, the trend of increasing drought and the recurrence of long-term cycles of wet and drought are evident. The study of phenology characteristics of rainfed crops (barley) in relation to climate conditions revealed that an increase in thermal and water stress has a direct effect on the performance of rainfed crops. Therefore, an increase of 2.5 °C in the average temperature, combined with a lack of moisture supply during flowering, results in a decrease in the number of seeds per spike (16 seeds per spike) and, consequently, a decrease in the plant's yield. At various growth stages of rain-fed plants, the correlation index between LAI harvested by direct methods and remote sensing methods ranges between 0.57 and 0.96. This value represents the precision of remote sensing techniques. From 1991 to 2017, the correlation index values between the yield of rainfed plants, especially wheat and barley, and the values of various drought indices indicate a positive and direct relationship between yield and drought index values. The correlation index between yield and drought index values reaches its maximum value during 1-6 months, and its value decreases as time scales become longer. The physiological properties of various products are one of the primary causes of this circumstance. On the basis of the obtained results, it can be concluded that the increase in drought and heat stress in the province of Lorestan and the county of Aleshtar has caused a decrease in yield at various stages of plant growth and an increase in water demand for a variety of rainfed crops.

Highlights

- According to drought indices, Aleshtar are experiencing increasing drought and long-term cycles of wet and dry.
- A temperature increase of 2.5 °C combined with a lack of moisture during flowering reduces the number of seeds per spike and the plant's yield.

* Corresponding author.
E-mail address: zand.m@scwmri.ac.ir
https://doi.org/10.22034/aes.2023.365450.1045

- From 1991 to 2017, correlation index values between rainfed plant yields, especially wheat and barley, and drought indices indicate a positive and direct relationship.
- Based on the results, it can be concluded that drought and heat stress in Aleshtar have decreased yield at various growth stages and increased water demand for rainfed crops.

1. Introduction

Despite the high risks of drought occurrence and its impact on agriculture, there have been few studies on the impact of drought on agricultural products in Iran. This is despite the fact that the occurrence of this phenomenon in any part of Iran has the possibility of happening for several years. On the other hand, in some areas, such as the southwest of the country, agriculture is the main source of people's income. Lorestan province, located in the southwest of Iran, is one of the provinces where agriculture is one of the main activities of its residents. In Lorestan province, agricultural activity is both rainfed and irrigated. Agriculture encompasses the cultivation of grains, legumes, industrial, and fodder plants, as well as the raising of livestock and aquatic animals. Therefore, the occurrence of drought in this region will have many adverse effects on the agricultural sector (Zand, 2018). Yang et al. (2006) analyzed the leaf area index using a combination of Terra and Aqua satellite data. They stated that there is no significant difference in the leaf area index obtained from these two satellites on a large scale. Deng et al. (2006) presented a new method to retrieve the leaf area index using satellite images. Garrigues et al. (2008) studied the sensitivity of leaf area recovery estimated by Li-Cor LAI-2000 optical instruments, AccuPAR, and hemispherical imaging methods in the above fields. The results showed that the hemispherical photography method has the least sensitivity to light conditions and is better than other tools for estimating the lower vegetation canopy. Yingbin et al. (2010) estimated the yield of rice crops in cold climatic conditions by using MADIS and Landsat images based on the leaf area index.

Sepulcre-Canto et al. (2012) developed a moisture index to detect agricultural drought in Europe. In this research, the standard precipitation index (SPI), soil moisture anomaly, and photosynthetic active radiation anomaly (FAPAR) absorbed by plants were used. The calculation of this composite index at the European level showed that this index provides a general and synoptic view of the drought situation in the form of a specific classification. Pérez-Blanco and Gómez (2014), in a study entitled "drought management programs and available water in the agricultural sector," examined a risk assessment model for a basin in southern Europe and concluded that if drought management programs are successfully implemented, available water will meet an average of 62.2% of current demand, and this figure may decrease to 50.2% by the end of the century as a result of climate change. Meroni Dutta et al. (2015) monitored agricultural drought through NOAA-AVHRR Sanjand NDVI data for a long-term period. They calculated the index (VCI) for the whole of Rajasthan and succeeded in obtaining a significant relationship between the rainfall anomaly index and the crop anomaly index. Meroni et al. (2017) conducted research titled "evaluation of the standard precipitation index" in order to provide an initial forecast of the state of seasonal vegetation in the Sahel region. By examining the relationship between the standard precipitation index and standardized cumulative measurements of active photosynthetic radiation (zCFAPAR[†]), they concluded that there is a significant linear relationship between these two variables in 32-66% of the studied area.

Ahmadi et al. (2010) estimated the cultivated area of soybean and corn with satellite images and stated that the LAI index could be used to identify vegetation and cultivated products, including soybean and corn. Bakhsandeh et al. (2014) measured the leaf area index for wheat plants using the AccuPAR device using two direct (destructive sampling) and indirect methods. The results showed that there is no significant difference between the figures and the two conditions in terms of the coefficients of the equation. Fatehi Marj et al. (2011) evaluated the drought of pasture and rain for three years, from 2007 to 2009, using Modis -measured images. In this research, it was found that the reduction of vegetation cover in the country in 2018 was significant. The comparison of the meteorological drought with the agricultural drought shows the adaptation of both droughts this year. At the same time, in 2019, despite the lower-than-average rainfall, the condition of the pasture cover was the wettest of the year.

Mirmusoi and Karimi (2013) investigated the effect of drought on the vegetation of Kurdistan province during the period 2000-2009 using the images of the Modis sensor. The results showed that there is a high correlation between the average SPI and NDVI indices at a significance level of 1%, and with a decrease of approximately -0.20 of the SPI index, an average of 1.2% of the weak vegetation area increases. Nowrozi and Mohammadi (2016) studied the effect of hydrological drought on agriculture in the Lanjan region using the SWSI index and the Mann-Kendall test. Their results showed that the production, cultivated area, and yield of crops in the region are decreasing. Among crops, only the amount of production and cultivated area of rice are increasing. Zand (2018) investigated the economic effects of drought on the income of dryland farmers (wheat and barley) in Khorramabad city over 15 years using SPI, PN, and DI indices. The results of this research showed that the effect of the SPI, PN, and DI indices on the yield and net value of wheat production was significant at levels of 0.01 and 0.05, respectively, and for the barley product at levels of 0.05 and 0.01, respectively.

According to the estimates made by the disaster headquarters of Lorestan governorate in the crop year

[†] z-score of the cumulative value of the Fraction of Absorbed Photosynthetically Active Radiation

2014–2015, the drought caused 1300 billion riyals of damage to the gardens and lands of the province. Drought has affected the amount of demand for agricultural inputs, such as fertilizers, poisons, machinery, credits, etc. In addition, the drought has had a negative impact on water resources, forests, pastures, and other natural resources in the province. In Lorestan province, agricultural activity is carried out in both rainfed and irrigated forms, in the groups of cereals, legumes, industrial, and fodder plants, livestock, and aquatic animals. The most damage caused by drought in the last few years has been directed at the agricultural sector. Precipitation and its characteristics are very important in all aspects of agriculture, and the amount of the crop is strongly influenced by the spring rainfall, especially in May. In the meantime, the agricultural drought causes problems, such as the reduction of household income (which has caused the amount of investment in this sector to also degrade), increasing unemployment among rural communities (migration), decreasing the number of livestock, and decreasing the production of crops, horticulture, livestock, and aquatic products. In this research, an attempt has been made to investigate the effect of drought on the production of rainfed agricultural products in Aleshtar County and its effects using a combination of field, modeling, remote sensing, and statistical methods.

2. Materials and Methods

2.1. Geographical location of Lorestan province

The studied area includes Lorestan province in the west of Iran. This province, with an area of 28559 square kilometers in the west of Iran, covers 1.7% of the total area of the country. Lorestan province is located in the west of Iran, with longitudes ranging from 32.37° to 34.22° E and latitudes ranging from 46.51° to 50.3° N . Lorestan province is bordered by Markazi and Hamadan provinces from the north, Khuzestan province from the south, Isfahan province from the east, and Kermanshah and Ilam provinces from the west. Figure 1 shows the location of Lorestan province by city division in Iran. (Climatic Atlas of Lorestan Province, 2016).

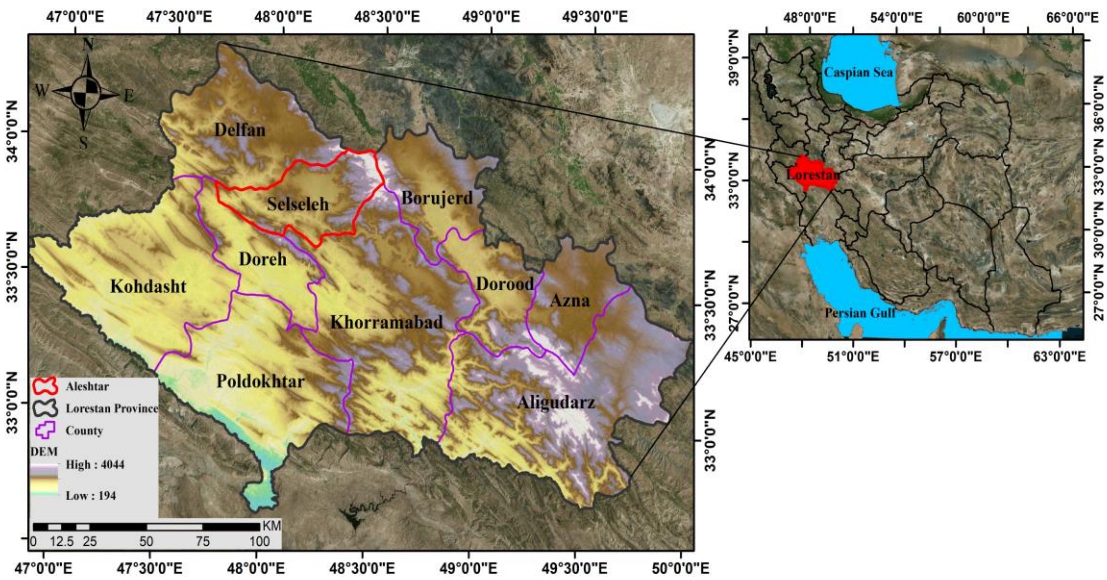

Figure 1. The location of Lorestan province

2.2. Data and methodology

2.2.1. Data

The data used to conduct this research includes field data, satellite information, and station data from the Meteorological Organization and the regional water company.

1. Land use map of Aleshtar county obtained from satellite images
2. Moody's satellite images on a daily scale and on an 8-day time scale
3. Field information collected using an AccuPAR device
4. Drought indicators calculated in the meteorological drought assessment project of Lorestan province
5. Information on the phenology of the rainfed barley crop at the Silakhor Agricultural Climate Research Station

2.2.2. Method

In this research, first, library studies and a review of sources related to the project were carried out to determine the general framework of the research. In the following, using field studies and interviews with provincial and Aleshtar county experts, sample fields were selected to harvest leaf area index and other plant characteristics during the growth period until harvest. In the following, the images of the Modis sensor during the growth period until the harvest of the selected fields in the water year of 2020 were determined. The images from this sensor were received at the specified times, and the leaf area index was calculated. Also, by using the AccuPAR Model LP-80 device, the characteristics of the products of the selected rainfed farms (leaf level, amount of radiation available at the top and bottom of the plant community, amount of active photosynthesis, peak angle of the sun's radiation) were collected. These two processes (taking pictures and harvesting with the AccuPAR device) were continued until the harvest stage. After conducting library and field studies, the drought conditions of the province were investigated based on the drought indicators calculated in the meteorological drought assessment project of Lorestan province. In this regard, SMI[‡], SPI[§], SPEI[**], RDI[††], NDVI[‡‡], VCI[§§], VHI[***], and TCI[†††] indexes were investigated based on the data of the synoptic station of Lorestan province and neighboring provinces from the period 1990-2017. Using their results, the spatial and temporal changes in drought occurrence on time scales of 3, 6, 9, 12, 18, and 24 months were investigated at the province level. Finally, by using the principal components method (PCA[‡‡‡]), the aforementioned indices were combined, and a composite index was extracted. The combination of indicators was performed in the MATLAB 2019a software. The combined results of drought indicators were prepared using the capabilities of GIS and MATLAB software in the form of maps, charts, and necessary tables.

After the temporal and spatial investigation of the meteorological drought that occurred in the province, in the continuation of leaf surface indices using satellite images and ground collection, the index of absorbed photosynthetically active radiation (FAPAR[§§§]) was calculated. Finally, the relationship between meteorological drought and the yield of rainfed crops was investigated with the use of regression relationships.

3. Results and Discussion

After examining the general conditions of drought in Lorestan province for different regions, drought values for rainfed crops were also calculated and analyzed separately for each city. It should be mentioned that the calculation of different drought indicators was done on different time scales. However, to avoid lengthening the report, we refrained from presenting graphs of all time scales, and only 12-month scale graphs were displayed. Figures 2–4 show the values of different drought indices in the rainfed areas for Aleshtar, Khorram Abad, and Borujerd counties. According to the results obtained on the graph in the studied area, the occurrence of droughts from the late 2001s to the middle of the 2011s is significant. According to the obtained results, the drought that occurred during the 2017–2018 water year is one of the most severe droughts in terms of rainfall recorded in the region. As can be seen on the graphs, during recent years, the water year 2017–2018 had drought conditions, the water year 2016–2017 had normal conditions, and the water year 2015–2016 had drought conditions.

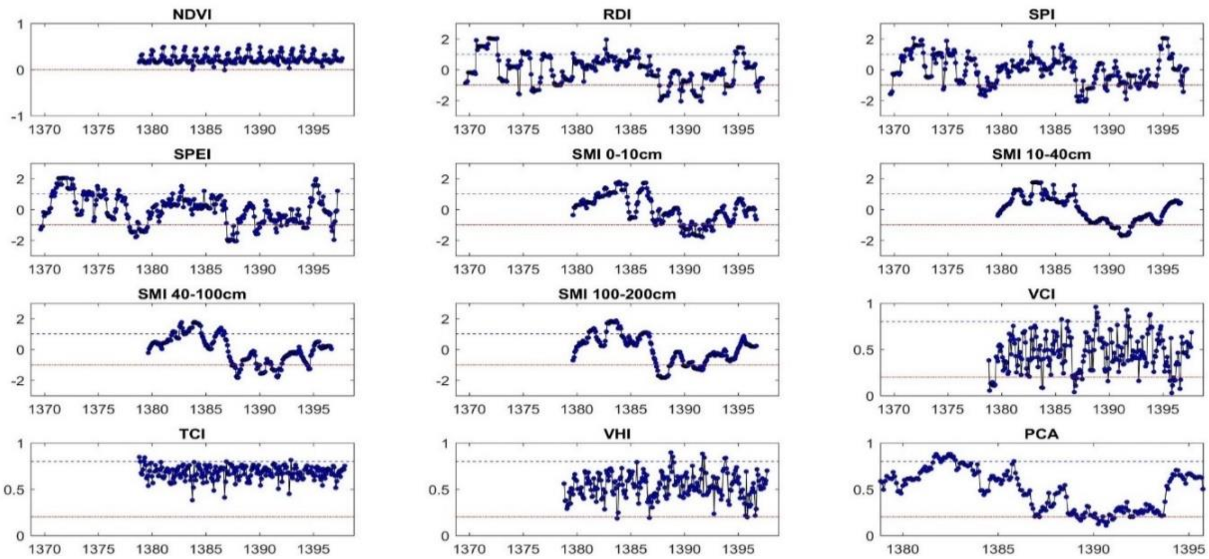

Figure 2. Time series of different drought indicators on a 12-month time scale (SPI, RDI, NDVI, SPEI, SMI, VCI, TCI, VHI, PCA) for the cultivation area of rainfed plants in Aleshtar county

3.1. Investigating the phenology characteristics of rainfed crops using laboratory operations

In order to monitor the relative performance of rainfed crops and investigate the phenology characteristics of rainfed crops in the study area in different stages of growth, information on the phenology of rainfed crops was collected and analyzed at the only agricultural climate research station in Lorestan province, namely Silakhor station, from the General Meteorological Department of Lorestan province. The phenology characteristics of rainfed barley during different stages of growth from January 2021 to June 2021 are explained here, and the yield

[‡] Soil Moisture Index
[§] Standardized Precipitation Index
[**] Standardised Precipitation-Evapotranspiration Index
[††] Reconnaissance Drought Index
[‡‡] Normalized Different Vegetation Index
[§§] Vegetation Condition Index
[***] Vegetation Health Index
[†††] Temperature Condition Index
[‡‡‡] Principal component analysis
[§§§] Fraction of absorbed photosynthetically active radiation

and other agricultural traits of this rainfed crop at Silakhor station are presented in Table 1. In the crop year 2020-2021, in most of the temperate regions, such as the Silakhor plain (located in Borujerd, the city of Lorestan province), we saw a relatively mild winter, which resulted in an increase in daily temperatures compared to long-term statistics. In addition, there was no effective rainfall from March 20 to April 16, which coincided with the time of sprouting. The lack of rainfall, along with the relative increase in temperature, led to a decrease in the length of the growing season, and finally, cereals with a low plant height (35 cm for rainfed barley) entered the reproductive stage. The results of the percentage of plants in the stemming stage also show the same thing. According to the results, the plants entered the pregnancy stage with 75% of the stems. This indicated that there was a competition for resources between spike growth and stem elongation.

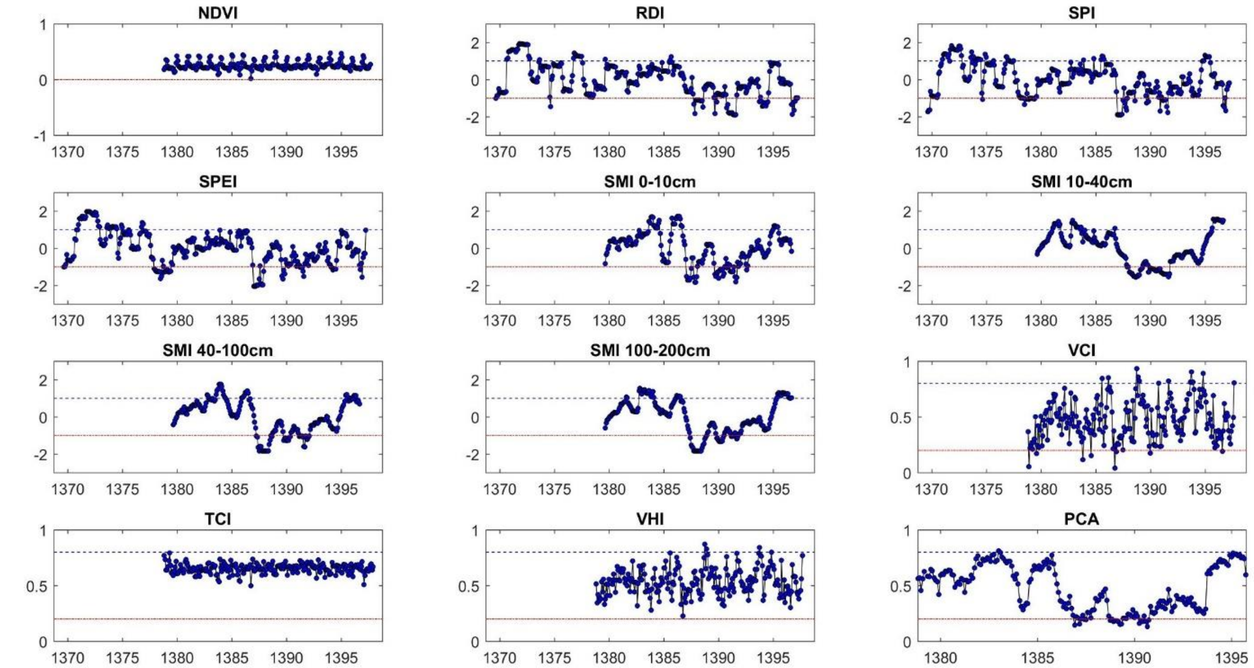

Figure 3. Time series of different drought indicators on a 12-month time scale (SPI, RDI, NDVI, SPEI, SMI, VCI, TCI, VHI, PCA) for the cultivation area of rainfed plants in Khorramabad County

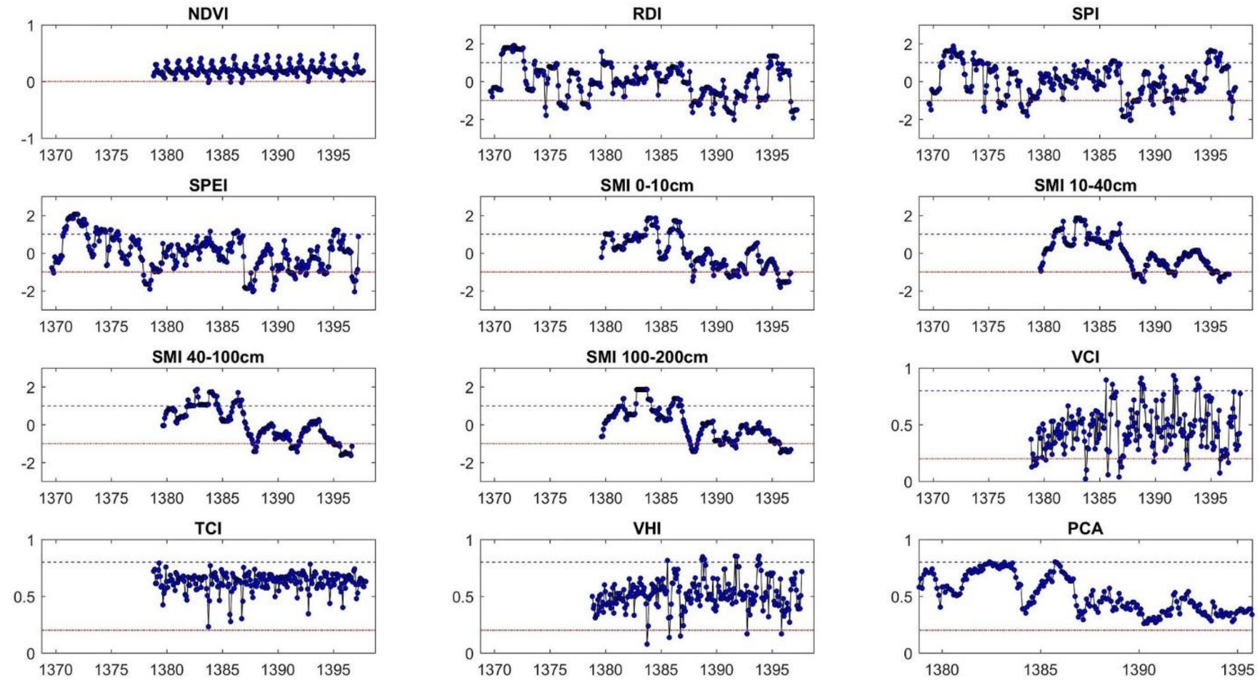

Figure 4. Time series of different drought indicators on a 12-month time scale (SPI, RDI, NDVI, SPEI, SMI, VCI, TCI, VHI, PCA) for the cultivation area of rainfed plants in Borujerd County

The number of spikes per unit area is influenced by the number of claws. Pinching is done from the stage of 3–4 leaves to the beginning of the stem elongation period. With the lengthening of the stem and the formation of the canopy, the competition between the claws begins, which eventually leads to the death of some claws. Due to the lack of rain during the stemming stage, which was from May 22 to April 16, and the average temperature increase of 1.7 degrees Celsius compared to the long-term average temperature, the number of fertile paws decreased from 370 paws per square meter to 360 paws per square meter (ten Sterile paws per square meter).

Ten days before the spike, which coincided with April 14 to 24, and during the spike, which coincided with April 24 to May 10, moisture stress led to a decrease in the number of spikes, especially in the tips of the spikes, which in turn resulted in a decrease in the number of seeds per spike. During the 30 days before flowering, for every one-degree increase in temperature above 14°C, the number of seeds decreases by 4%. The average temperature in the period from April 10 to May 10, which coincides with the 30-day period before flowering, was above 14°C and between 15-20°C on most days.

In the period from May 12 to 18, which coincided with the flowering time, the increase in wind speed (especially on May 15) led to an increase in evaporation from the soil surface, as well as an increase in temperature by 2.5 degrees Celsius compared to the long-term average temperature in this region. The period of drought stress caused damage to grain fields and subsequently reduced grain yields in dry lands. Thus, the drought stress conditions in the flowering stage led to a decrease in the number of seeds per spike (16 seeds per spike). In other words, the decrease in yield due to drought stress in the flowering stage was caused by the decrease in the number of seeds in the spike. In addition, it is important to create favorable soil moisture conditions, especially in the tillering, stemming, and spike emergence stages, for the formation of the number of seeds per unit area. According to the rainfall statistics from February 27 to April 16, which coincided with the aforementioned growth stages, only one effective rainfall (27 mm on May 13) occurred.

The weight of 1000 seeds is determined as one of the important yield components from the time interval of pollination to maturity. The seed filling time is mainly affected by temperature. As it is clear from the results, from May 18 to June 20, which coincides with the seed-filling period, the average temperature increased by 1.6 degrees Celsius. Also, due to the fact that there was no rainfall during this period, the moisture stress at this stage (when the seeds are filled) reduces the photosynthetic capacity through premature aging of the leaves. In this way, the length of time that carbohydrates can be transferred to the grain is reduced, which is equal to the reduction of the duration of grain filling and, ultimately, the weight of a thousand seeds.

Table 1. the yield and other agricultural traits of rainfed barley at Silakhor station

Traits	Yield
Plant height (cm)	62
Number of spikes per square meter	370
The number of fertile spikes	360
The number of unproductive spikes	10
Number of seeds per spike	16
Thousand seed weight (grams)	21
Seed yield (kg/ha)	2500
Straw yield (kg/ha)	1900

3.2. AccuPAR leaf surface index

Table 2 shows the index values of plant leaf area of selected farms (in the crop year 2020-2021) in the study area. Field harvesting from selected fields has been done on four dates at different stages of wheat plant growth. Based on the values presented in Table 2, the wheat plant leaf area index values during a logical process from the early stages of growth to the peak growth stage in May increased. Simultaneously with the ripening of the crop and harvest, LAI index values decreased; in other words, simultaneously with the increase in the number of leaves and the area of wheat and barley plants in the region, the index values also increased. Among other notable points on the graph below (Figure 5), we can mention the difference in the amount of leaf surface obtained in each period at different stages of plant growth for sample farms. So in one stage, for example, spike formation, the amount of leaf surface is different in the fields under study. One of the reasons for this can be the difference in the types of planted species and the effect of microclimatic factors on different farms.

Table 2. the index values of plant leaf area of selected farms

	2021-04-13	2021-04-28	2021-05-18	2021-06-01
Sarab-e Honam	0.02	0.14	1.11	0.31
Chahar Takhteh	0.01	0.08	0.36	0.28
Nurullahi	0.05	0.21	0.31	0.055
Deh-e Kadkhoda	0.07	0.05	0.62	0.43

Figure 6 shows the index values of wheat plant leaf area in selected fields of Aleshtar county. Based on the values obtained from MODIS satellite images on the days of harvesting with the AccuPAR device, the maximum value of the leaf area index of the dominant crop in the region occurs in the villages of Nurolahi and Chahartakhteh in the middle of May and the villages of Sarab Hanam and Deh Kodkhoda in early may Among the causes of this difference is the maximum time of the leaf surface index. Accordingly, the timing of processing and harvesting can be affected by the type of product variety and the effect of microclimatic factors on different farms.

Examining the relationship between the values of the leaf area index harvested using the AccuPAR device and the images of the Modis sensor showed that, although there is a difference between the values harvested at different stages of plant growth in the region, despite this behavior, the values of the leaf area index harvested by the Modis sensor and the AccuPAR device are similar. Tables 2–3 show the R index values between the data taken by the AccuPAR device and the Modis sensor at different stages of growth. As it is clear, there is a direct relationship between these two tools when harvesting the plant leaf surface index. In our stage, the maximum relationship was obtained before the maximum greenness. The difference in the types of planted varieties can be one of the reasons for the lower values of the correlation index in the stage of maximum greenness.

Table 3. Value of correlation indices and coefficient of determination between LAI data collected by Acupar and MODIS satellite

Time	R	R2
2021-04-13	0.78	0.61
2021-04-28	0.96	0.94
2021-05-18	0.57	0.32
2021-06-01	0.6	0.36

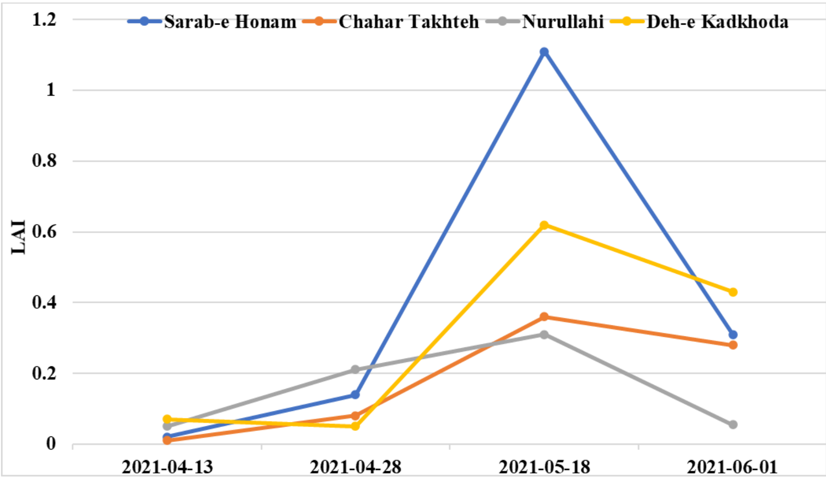

Figure 5. Leaf area index values of rainfed wheat for different farms based on the estimate of AccuPAR

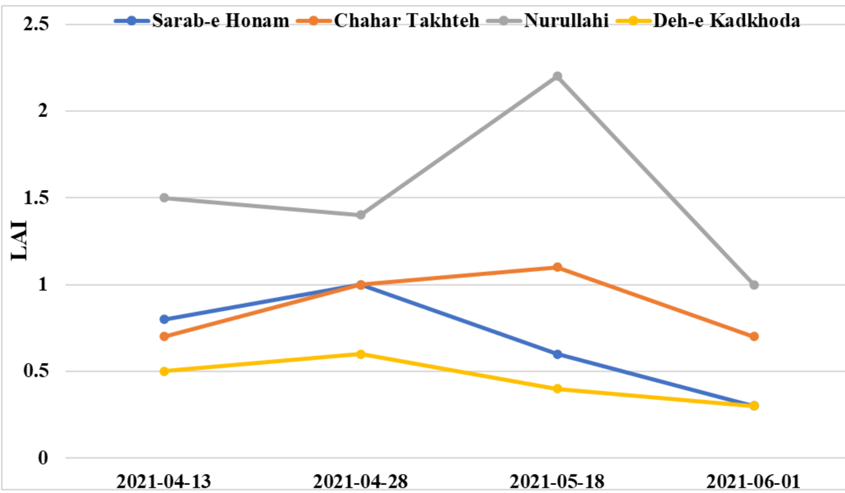

Figure 6. Leaf area index values of rainfed wheat for different farms based on the estimate of MODIS satellite images

3.3. Relationship between the performance of rainfed plants and drought in the long term

In this part, the relationship between the yield of rainfed plants and the values of drought indicators in Lorestan province has been investigated. Figure 7 shows the correlation between the yield of rainfed atmosphere in Lorestan province and various drought indicators used in this research. Indices such as NDVI, Standardized NDVI, or SNDVI, SPI, RDI, SPEI, SMI1 (at a depth of 0 to 10 cm), SMI2 (at a depth of 10 to 40 cm), SMI3 (at a depth of

40 to 100 cm), and SMI4 (at a depth of 100 to 200 cm): all these indicators are in time series of 1, 3, 6, 9, 12, 18, and 24 months. VCI, TCI, and VHI indices, and finally the combined drought index based on PCA, which is also in the time scales of 1, 3, 6, 9, 12, 18, and 24 months. The red dashed lines that appear horizontally on the chart show the range of each indicator. Since some indicators have different time scales (such as SPI), they have also been assigned a larger range. In the range of indicators with a time scale, the column charts belong to the time series of 1, 3, 6, 9, 12, 18, and 24 months, respectively. Within the polygon of each county and in each water year, the average drought indices were adapted and then correlated with the yield of rainfed wheat and barley in the cities. Figure 7 shows the correlation between different drought indicators and rainfed performance in different cities of Lorestan province. About rainfed barley, as with rainfed wheat, the short-term time scales of drought show a greater correlation with the yield of rainfed barley. However, on long-term time scales, even this correlation is reversed. Although the analysis of these results needs more investigation, it seems that the vegetative period of barley is shorter than that of wheat. Therefore, it shows a stronger correlation than drought indicators with a smaller time scale.

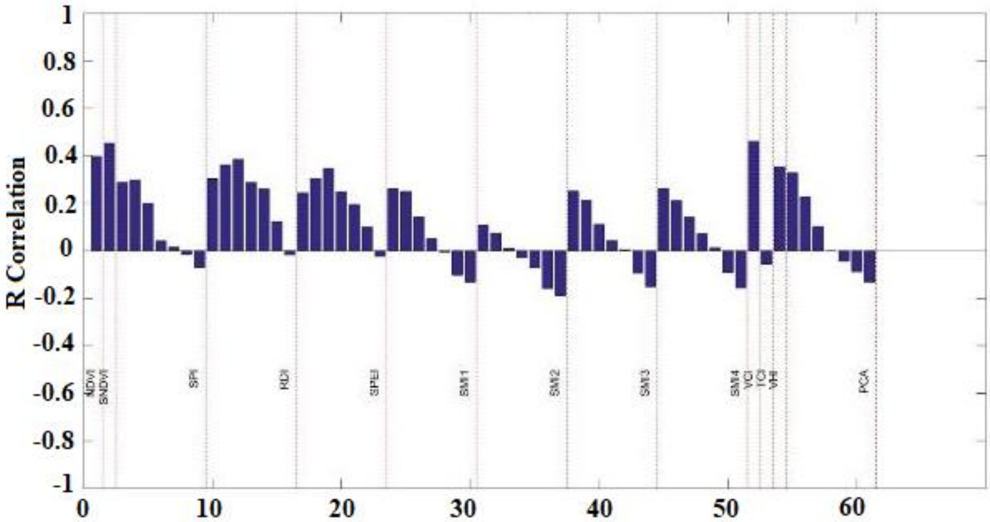

Figure 7. Value of Correlation index between drought indices and rainfed barley yield in Lorestan province

4. Conclusion

Water shortages and droughts are two of the biggest challenges the country's agricultural development will face now and in the future. Estimates of food needs show that if a suitable strategy for water management and preparation to reduce the effects of drought is not adopted in the agricultural sector, the water and land potentials of the country will not provide the food needs the country. The main goal of this research is to estimate the values of the leaf surface index using direct and indirect methods and to finally reach a suitable method for estimating the yield of the product. To achieve this goal, a combination of telemetry, statistical, and field-laboratory methods were used. The information used includes the daily images of the Modis sensor and samples taken from fields during different stages of wheat plant growth in Aleshtar county.

Calculation and analysis of drought indices (especially the meteorological drought indices RDI and SPI) in order to monitor the drought conditions of Lorestan province during 1991–2017 showed that the increasing trend of drought and the repetition of long-term cycles of drought and wet are evident in Lorestan province. In fact, based on the results related to drought indicators (Figures 2–4), three cycles of drought and wet were observed during the period under review. The first cycle is before 2011, which ended in a significant drought around 2011. In the next stage, this cycle peaked again and ended in a significant wet period in the years around 2017. However, this period of wetness is less severe than the previous one that happened around 1994. The occurrence of long-term droughts during the years 2008 to 2015 is evident, and we witnessed the creation of a wet period again in 2017. The decrease in the intensity of rain and the increase in the duration of droughts, as well as their severity, can indicate climate changes in recent years.

Processing and the results of field and laboratory harvests showed that the amount of leaf surface during the growth period shows an upward trend until a certain stage and then a downward trend. Thus, the maximum amount of leaf area is in the flowering period. As the harvest stage approaches and most of the plant's energy is focused on its performance, the increase in the plant's leaf area decreases, and over time and near the time of harvest, the trend of greenness and the plant's leaf area decrease. The results obtained from processing the data recorded at the Silakhor agricultural station and in the laboratory environment showed that it is important to create favorable thermal and soil moisture conditions, especially in the tillering, stemming, and spike emergence stages, for the formation of the number of seeds per unit area. By increasing the temperature at the wrong time, the barley plant will face stress, so that in the stemming stage, with an increase of 1.7 degrees Celsius in the average temperature compared to the long-term average temperature, the number of fertile claws decreased from 370 claws per square meter to 360 claws per square meter. Also, in the period from May 12 to 18, which coincided with the flowering time, the increase in wind speed (especially on May 15) and the increase in temperature by 2.5 degrees Celsius compared to the long-term average temperature caused drought stress conditions and reduced the number of seeds per spike. Based on the results obtained in the laboratory environment, the barley yield per hectare is estimated to be 2500 kg.

The results of investigating the relationship between the yield of rainfed plants and various drought indices in Lorestan province during the period 1991–2017 showed that the values of the correlation index between the yield of rainfed plants and most of the drought indices are positive, although the correlation index is different at different time scales. Is. The positive correlation values between the performance of rainfed plants and different drought indicators indicate a direct relationship and influence between the performance of rainfed plants and the amounts of rainfall and moisture in the soil. As a result, with the increase of rainfall and soil moisture, the amount of yield increases, and with the decrease of rainfall and moisture in the soil, the amount of yield also decreases. It is also necessary to mention that although the correlation index values between the yield of rainfed plants and the values of drought indices are less than 0.5 in many cases and are not very high, it should be considered that crop yield is not only a function of drought and the indices The other factors, especially the weather conditions and especially the temperature conditions, farm management, the timely availability of inputs, etc., also affect the yield of crops. Also, in a fixed cultivation area in a region or province, the occurrence of drought, wetness, or other factors can lead farmers to produce another crop. Therefore, the process of analyzing the available information is very complicated. In addition to the mentioned cases, since there is still no up-to-date location system related to the collection of agricultural statistics for the country, the accuracy of the collected statistics can also be another source of uncertainty in the correlation calculations between actual and estimated performance. However, high correlations are not expected here, and it seems that the correlations are more reasonable at the current level.

Reference

Ahmadi, H., Mastali, A. R., & Tabatabaeifar, S. A. (2010). Corn and soybean recognition and an estimation of the planted area, using remote sensing in Dasht-e-Naz agro-industrial company. Iranian Journal of Biosystems Engineering, 41(1), 53–60. **doi:10.1007/978-3-642-15479-9-5**

Bakhshandeh, E., Soltani, A., & Ghadiryan, R. (2012). Leaf area index measurement by AccuPAR instrument in wheat. Journal of Plant Production, 18(4), 97–101.

Borken, W., et al. (2006). Effects of experimental drought on soil respiration and radiocarbon efflux from temperate forest soil. Global Change Biology, 12, 177–193. **doi:10.1111/j.1365-2486.2005.001058.x**

Deng, F., Chen, J. M., Plummer, S., Chen, M., & Pisek, J. (2006). Algorithm for global leaf area index retrieval using satellite imagery. IEEE Transactions on Geoscience and Remote Sensing, 24, 2219–2229. **doi:10.1109/TGRS.2006.872100**

Dutta, D., Kundu, A., Patel, N. R., Saha, S. K., & Siddiqui, A. R. (2015). Assessment of agricultural drought in Rajasthan (India) using remote sensing derived vegetation condition index (VCI) and standardized precipitation index (SPI). The Egyptian Journal of Remote Sensing and Space Sciences, 18, 53–63. **doi:10.1166/jcp.2010.1003-987-4**

Fatehi Marj, A., Hosseini Hosseinabadi, F., Gomrokchi, A., & Namaki, M. (2011). Agricultural drought risk management plan, case study: Alamut River basin in Qazvin. National Agricultural Drought Management Database, Soil Conservation and Watershed Management Research Institute, Tehran.

Garrigues, S., Shabanov, N. V., Swanson, K., Morisette, J. T., Baret, F., Myneni, R. B. (2008). Intercomparison and sensitivity analysis of leaf area index retrievals from LAI-2000, AccuPAR, and digital hemispherical photography over croplands. Agricultural and Forest Meteorology, 148, 1193–1209. **doi:10.1111/hex.12487. 2017.11.014**

Hogg, E. H., Brandt, J. P., & Michaelian, M. (2008). Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. Canadian Journal of Forest Research, 38(6), 1373–1384. **doi:10.1080/02626667.2018.1560449**

Meteorological Office of Lorestan Province. (2016). Climate atlas of Lorestan province using geographical information system (p. 220). **doi:10.1016/j.jpsychires.2017.11.014**

Miri, M. (2016). Analysis of relationship between forest decline and climate changes in Ilam province (Ph.D. Thesis). University of Tehran.

Mirmosavei, S., Kareimei, H. (2013). Effect of drought on vegetation cover using MODIS sensing images case: Kurdistan province. Geography and Development, 11(31), 57–76. **doi:10.1016/j.copsyc.2015.09.005**

Norouzi, A., Mohammadi, Z. (2016). Survey of hydrological drought and its effects on Lenjan agricultural. Spatial Planning, 21(2), 97–116. **doi:10.20.1001.1.22287485.1395.6.2.7.7**

Sepulcre-Canto, G., Horion, S., Singleton, A., Carrao, H., & Vogt, J. (2012). Development of a combined drought indicator to detect agricultural drought in Europe. Natural Hazards and Earth System Sciences, 12, 3519–3531.

Tadesse, T., Wilhite, D., Harms, S., Hayes, M., & Goddard, S. (2004). Drought monitoring using data mining techniques: A case study for Nebraska, USA. Natural Hazards, 33(1), 137–159. **doi:10.1023/B:NHAZ.0000035020.76733.0b**

Yang, W., Shabanov, N. V., Huang, D., Wang, W., Dickinson, R. E., Nemani, R. R., Knyazikhin, Y., & Myneni, R. B. (2006). Analysis of leaf area index products from a combination of MODIS Terra and Aqua data. Remote Sensing of Environment, 104, 297–312. **doi:10.1016/j.rse.2006.04.016**

Yingbin, H., Uchida, S., Huajun, T., Youqi, C., & Jia, L. (2010). Application of TERRA/MODIS images, TM images, and weather data to assess the effect of cold damage on rice yield. International Journal of Agricultural and Biological Engineering, 3, 31–38. **doi:10.3965/j.issn.1934-6344.2010.02.031-038**

Zand, M. (2001). Zoning of climate droughts in Lorestan province using statistical indicators. 01st National Conference on Mitigation of Water Crises, Zabol University. [In Persian]

Zand, M. (2018). The economic effects of drought on the income of dryland farmers (wheat and barley) in Khorramabad city. 7th National Conference on Rainwater Catchment Systems, Soil Conservation and Watershed Management Research Institute & Iranian Rainwater Catchment Systems Association. [In Persian]