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Study of Vegetation Status and Determination of Drought Intensity through Vegetation Indices Using Satellite Images

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Abstract

Knowledge of the quantitative and qualitative characteristics of changes in environmental planning, land- use planning and sustainable development is of great importance and today, the use of vegetation maps is one of the key pillars in information production for macro and micro- planning, and vegetation considered as one of the most important components of any ecosystem. Determining the percentage of vegetation in order to understand the interactions between the Earth and the atmosphere, its effect on climate, soil erosion, drought surveying, and natural resource management is essential. Since most of the methods proposed to assess drought conditions so far estimate drought indices based on stationary data at one point, researchers were looking for a way to better achieve regional estimates in order to better manage the damage caused by this gradual phenomenon. Therefore, in this research, remote sensing and Landsat 8 satellite imagery techniques and Infrared Percentage Vegetation (IPVI), Normalized Difference Vegetation Index (NDVI), Weighted Difference Vegetation Index (WDVI), Soil Adjusted Vegetation Index (SAVI), Optimized Soil Adjusted Vegetation Index (OSAVI) and Modified Soil Adjusted Index (MSAVI) were used to calculate the percentage of vegetation and the Modified Perpendicular Drought Index (MPDI) was used to estimate regional drought. After preparing the drought map, the areas which were in mild, moderate and severe drought in terms of severity, were well classified.

***Keywords**:* Vegetation, Drought, Remote Sensing, Satellite Images

1. Introduction

Drought, in contrast to other hazards, is one of the major natural hazards in terms of severity, duration and side effects, economic, social and biological (Abasali, 2021).One of the most important problems that human has been facing, especially in recent years is the water crisis and drought, and therefore it is important to study the drought situation in the optimal management of water resources, and water resources have long been a critical issue, especially in arid regions of the world. Currently, about 80 countries are located in arid regions of the world, and Iran is one of these countries due to rainfall scarcity and its inappropriate distribution. The existence of these conditions along with the rapid population

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growth and especially recent droughts in recent years have made water supply in the country one of the major challenges today (Karimi, Shahedi, and Khosravi, 2016). Drought is a natural event caused by a decrease in rainfall compared to its long-term average and can occur in any climate. This phenomenon causes a lot of damage to various sectors, including water resources (Taboozadeh et. al., 2013). Long-term drought could shut down much of agriculture and lead to economic crisis. (Abas ali, 2021). Drought is a phenomenon that occurs over a long period of time compared to other natural phenomena and has occurred in abundance at different times around the world (pilpaye Alireza,2019).

In the past, the conventional approach to drought monitoring was based on meteorological climatic observations and the use of climatic indicators, which these methods are point based because of the use of weather station statistics and additionally, the dispersion of stations, especially in arid areas, has created limitations in the study of drought. Over the last four decades, remote sensing has provided a wide range of drought monitoring tools and numerous drought monitoring models have been proposed, generally based on plant indices, land surface temperature, humidity and reflectance in the visible and infrared region (Khosefi et al., 2010). About 64.7% of Iran's area (105 million hectares) has arid and semi-arid climate, and the average rainfall of the country is less than one third of the world average annual precipitation and this amount does not have a right time and place distribution, and drought as a natural hazard has always affected different parts of the country (Baaghideh, Alijani, and Ziaian, 2011). Drought is one of the natural disasters that affects the socioeconomic status of society in the short, medium and long term. Among the natural events that have affected human societies, the effects of the drought phenomenon in terms of frequency, severity, duration and long-term social effects in society have been more than others. In addition, the difference between this phenomenon and other natural disasters is that unlike other disasters, this phenomenon acts gradually and over a relatively long period of time, so that its effects appear after several years and with a longer delay than other natural disasters. This shows the importance of drought monitoring in order to predict the probability of this phenomenon and its extent in the future (Fatehmarj and Heydarian, 2013). Drought is a condition of lack of precipitation and rising temperature that can occur in any climate. Drought is often described as a gradual phenomenon, and unlike floods and rainfall, which have a specific time of occurrence and termination, it is too difficult to describe its spatial and temporal (Alizadeh, 2007). Recently, remote sensing and techniques produced based on satellite images have been able to provide appropriate estimates of scale drought on a regional. The advantage of remote sensing methods over conventional interpolation methods such as geostatistics is that in methods based on remote sensing, satellite images are used that provide the spatial distribution of real values of variables affecting drought (including temperature and vegetation cover). Therefore, their results can be more accurate than interpolation methods. During the drought period, the amount of available moisture decreases and the temperature increases (Shakya and Yamaguchi, 2006). The benefit of satellite image data is their ability to enter directly into processing systems, which allows them to be quickly reviewed and updated (Jalili, 2005).

2. Materials and Methods

2.1. Study Area

Khorramabad city of Lorestan province is located between longitude of 48 degrees and 12 minutes to 48 degrees and 31 minutes and latitudes of 33 degrees and 20 minutes to 33 degrees and 34 minutes. This city leads from the north to the Hamedan and Markazi provinces, from the south to Khoozestan and Chaharmahal Bakhtiari provinces, from the east to Isfahan province and from the west to Ilam and Kermanshah provinces.

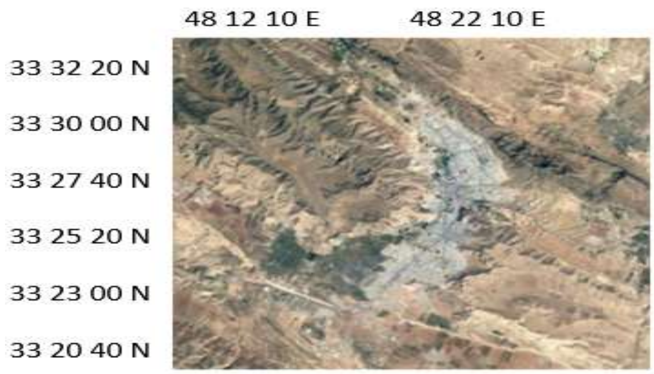


Figure 1. Location of the study area

2.2. Landsat 8 Images

After the retirement of Landsat 5 in early 2013, the Landsat 8 satellite was launched on 11 February. This is the eighth satellite in the Landsat satellite program, and the seventh that achieved orbit successfully. The satellite is the product of a collaboration between NASA and the United States Geological Survey (USGS). Landsat 8 captures imaging using two OLI sensors and another TIRS infrared thermal. Landsat 8 captures images using Operational Land Imager and Thermal Infrared Sensor (TIRS). OLI and TIRS sensors have more advanced technology to scan the Earth. Landsat point scanners have been replaced by Landsat 8 line scanners. Reducing bandwidth and increasing radiometric accuracy in these sensors has increased accuracy of performance. The two sensors collect image information for nine shortwave bands and two thermal wavelength bands, respectively. A significant feature of Landsat is the ability to study vegetation and land use change over time (Hosseini et al.,2014).

2.3. Normalized Difference Vegetation Index (NDVI)

One of well-known spectral indices of vegetation widely used in remote sensing studies is the Normalized Differential Plant Index (NDVI). This index is the difference between the maximum absorption in the red region through chlorophyll pigments and the maximum reflection in the infrared region due to the cellular structure of the leaf and is determined using bands of hyperspectral sensors as follows (Alavipanah, 2011).

$$NDVI = (NIR-RED)/(NIR+RED) \quad (1)$$

NIR: Infrared band
RED: Red band

2.4. Hyperspectral Soil Adjusted Vegetation Index (SAVI)

Due to changes in soil spectral properties, several indices with minimal sensitivity to canopy cover have been proposed. Changes that include a canopy correction factor are called soil modified index (L). Using narrowband hyperspectral sensors, SAVI is defined as follows (Alavipanah, 2011):

$$SAVI = \frac{(1+L)(nir-red)}{(nir+red+L)} \quad (2)$$

L is a function of vegetation density.

$$L = 1-2*NDVI*WDVI \quad (3)$$

2.5. Weighted Difference Vegetation Index (WDVI)

This index was first introduced by Clevers in 1988 and has a limited range of changes and is sensitive to atmospheric changes.

$$DVI = NIR - a * RED \quad (4)$$

: Slope of the soil line

2.6. Multispectral Modified Soil Adjusted Index (MSAVI)

Differences of the background soil

$$MSAVI = \frac{(1+L)\,(NIR - RED)}{(NIR + RED + L)} \quad (5)$$

2.7. Hyperspectral Optimized Soil Adjusted Vegetation Index (OSAVI)

$$OSAVI = \frac{(1+0.16)\,(R800 - R670)}{(R800 + R670 + 0.16)} \quad (6)$$

2.8. Infrared Percentage Vegetation Index (IPVI)

This index was first introduced by Crippen in 1990, and the range of changes of this index is from 0 to 1. This index is defined as follows (Alizadeh, 2007):

$$IPVI = \frac{NIR}{NIR + RED} \quad (7)$$

2.9. Modified Perpendicular Drought Index (MPDI)

Moisture is a major determinant in the occurrence of drought that is closely connected to spectral reflectance of soil. Modified perpendicular drought index based on moisture and vegetation percentage is presented and calculated from the following equation (Nouri,2019)

$$MPDI = \frac{RED + aNIR - Fv\,(R\,v,red + R\,v,nir)}{(1 - Fv)\sqrt{a^2 + 1}} \quad (8)$$

a= Slope of the soil line
NIR: Infrared band
RED: Red band
$R\ v, redR\ v, nir$ and vegetation reflection are in infrared band and red band.
Fv is obtained from the following relation:

$$F_v = \frac{Vi - Vi\ max}{1 - (Vi\ min - Vi\ max)^k} \quad (9)$$

Vi is a vegetation index and k is a fixed number that reduces the RMSE.

3. Results and Discussions

After performing all band calculations, first the index maps in ARC GIS software were obtained as follows. It is unstable and variable against soil color, soil moisture, and the effects of saturation of high-density vegetation. And NDVI vegetation index in the study area well indicates the amount of vegetation in the outskirts of the city (red area). In the northwestern part, the image is of red striped areas of mountainous areas and rocks or the least vegetation.

NDVI IPVI

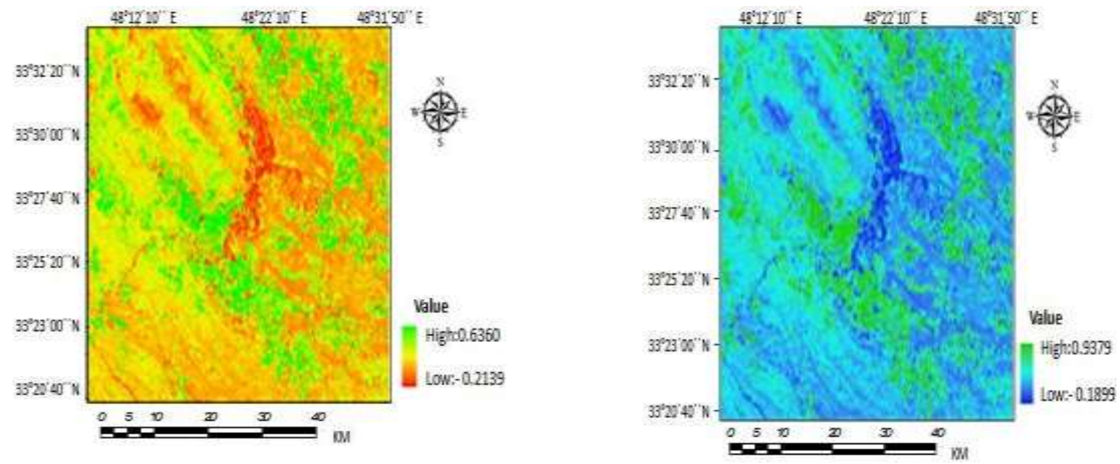
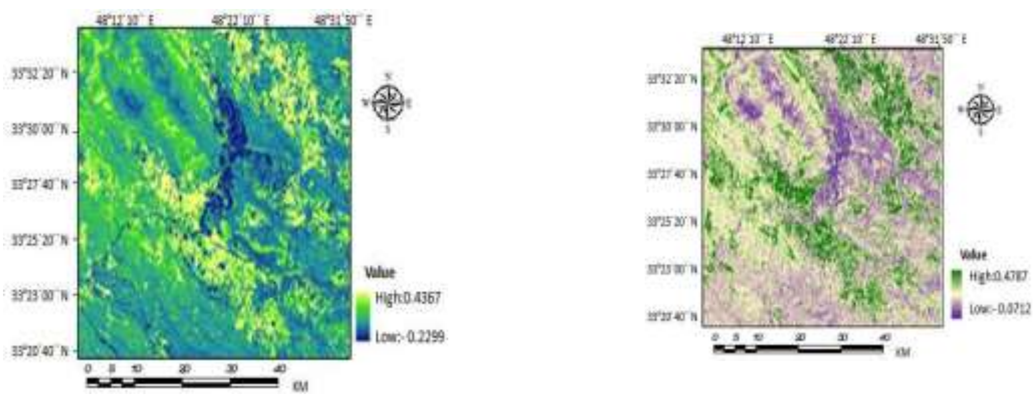


Figure 2. Map of IPVI and NDVI indices

The IPVI index in the image above actually shows the infrared percentage, which is the highest in the residential area compared to its surroundings. SAVI index reduces the effects of soil brightness on the red band spectrum, resulting in better and improved NDVI.



SAVI WDVI

Figure 3. Map of SAVI and WDVI indices

OSAVI index is more sensitive to vegetation than SAVI index and has more accurately extracted vegetation and reduced soil effect.

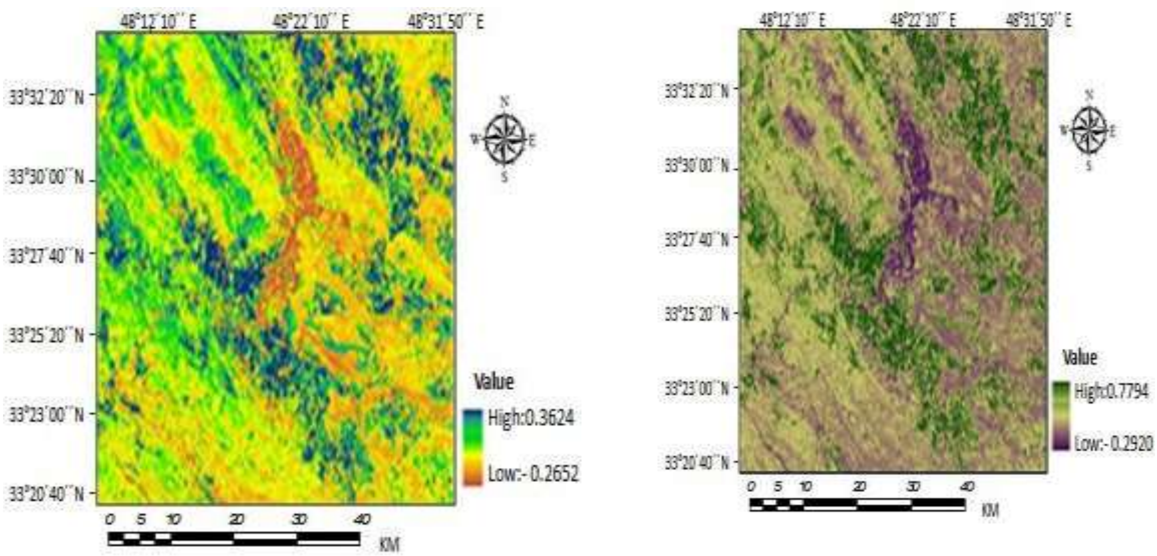


Figure 4. Map of MSAVI and OSAVI indices

By field research methods and land use in the region, the best indicator was MSAVI, which had the highest correlation (R2 = 0.87). Therefore, this index was used to study drought and vegetation percentage.

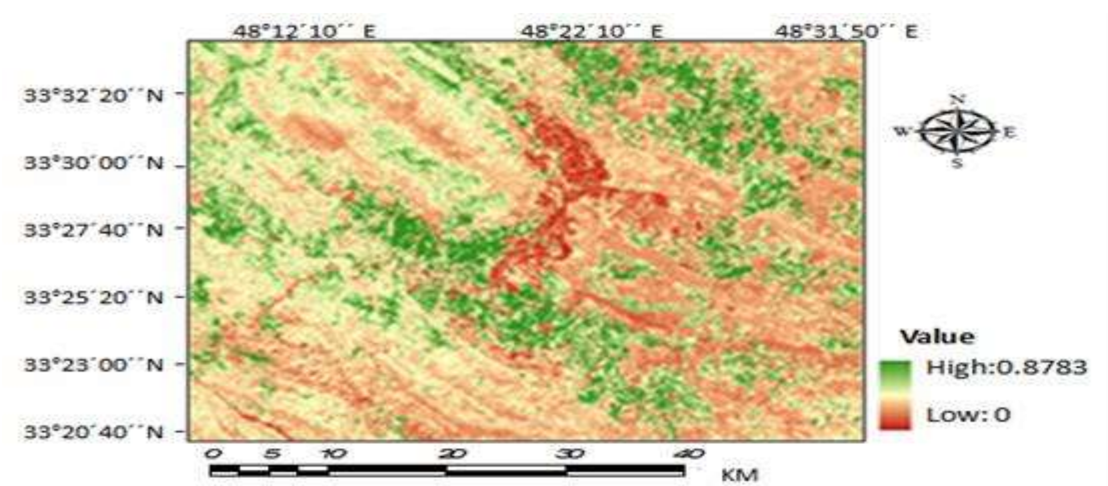


Figure 5. Vegetation percentage map

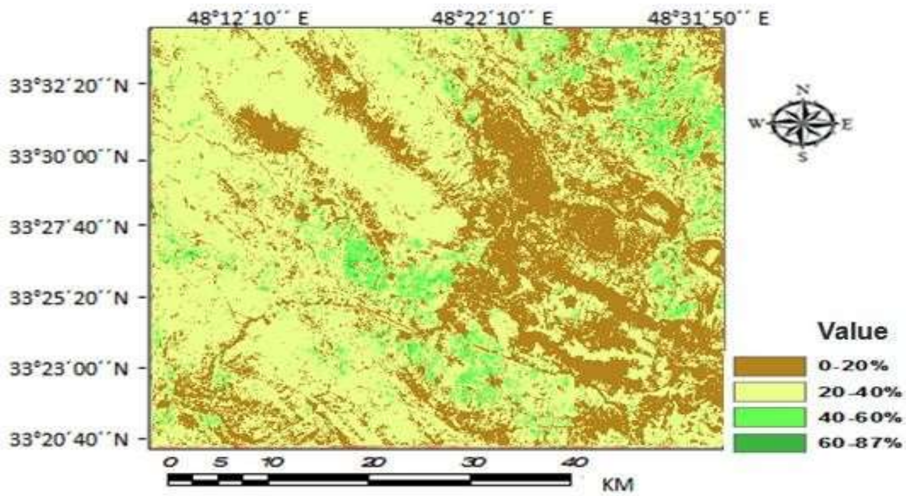


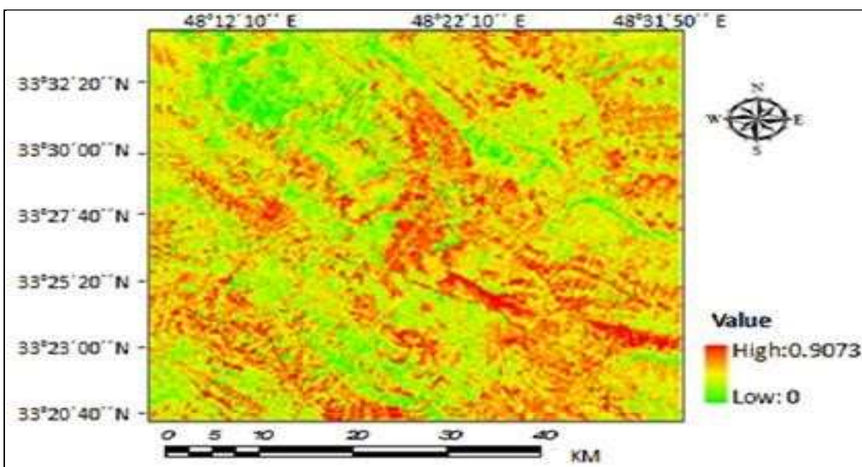
Figure 6. Reclassified map of vegetation percentage

Table 1. Percentage and area of vegetation

Area (Km^2)	Percentage of vegetation
253.24	0-20
461.84	20-40
46.77	40-60
1.37	60-87

By considering 100 points of wet and dry soil points in the study area, the linear relationship between bare soil reflection in red and infrared bands was calculated.

$$\text{Band (nir)}=1.07 * \text{band (red)} + 0.01 \quad (10)$$



MPDI	Drought conditions
0-0.2	Mild
0.2-0.4	Moderate
More than 0.4	Severe

Figure 7. Map of MPDI drought conditions

4. Conclusion

In order to create the drought risk map using satellite data in the region, six indices were used to optimally study the drought in the region. Among these indices, the MSAVI index had the highest correlation with the study area. Therefore, this index was used as the basis for calculating the percentage of vegetation and map of drought conditions. The final results indicate that the drought status is more severe in the southeastern regions of the study area than in other regions, and in the northwestern regions, the drought is milder. In general, according to the MPDI drought map, 44% of the study area is in slight drought, 55% of the study area is in moderate drought and only 1% of the study area is in severe drought.

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