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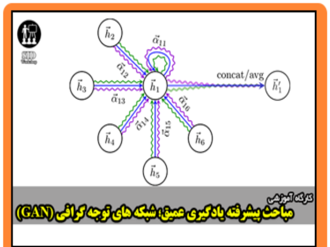

مباحث پیشرفته یادگیری عمیق؛ شبکه های توجه گرافی
(Graph Attention Networks)

کارگاه آنلاین آموزش استفاده از وب آو ساینس

کارگاه آنلاین مکالمه روزمره انگلیسی

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Use of remote sensing for drought assessment and monitoring

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Abstract

Drought is a natural disaster which occurs in all climate regimes and causes environmental, social and economic crises. There is no universal definition for that but it is broadly defined as "severe water shortage". Assessment and monitoring of this phenomenon due to its creeping status and large spatial coverage is difficult especially using ground-based measurements. To detect drought, we need a tool that can provide information about temporal and spatial distributions of this phenomenon. Remote sensing offers considerable advantages in drought assessment and monitoring. Since the launch of satellites which is more than three decades, various remote sensing data with different temporal, spatial and spectral resolutions has been widely and successfully used in this field. The success of this technology in drought monitoring and assessment can refer to repeatability, large converge and inexpensive data that are extracted from remote sensing imagery. Also, due to the lack of meteorological data such as rainfall and temperature in remote and broad regions which is a usual case in developing countries, remote sensing can provide a valuable source of information for drought monitoring. The aim of this paper is to introduce the most widely used remote sensing techniques such as the Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), Perpendicular Drought Index (PDI) and Modified Perpendicular Drought Index (MPDI) in drought studies. Because of the advantages of remotely sensed data over field measurements, information extracted from this data using remote sensing techniques can help government, non-government organizations, pastoralists and farmers to better understand the trends of drought and be more proactive in drought management.

Key words: remote sensing, NDVI, drought assessment and monitoring

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Introduction

Drought is a natural disaster which occurs in all climate regimes and causes environmental, social and economic crises. There is no universal definition for that but it is broadly defined as "severe water shortage". Some of the reasons for having no universal drought definition may refer to drought characteristics such as 1) its development is slow and almost without clear start and end; 2) its impact spreads over large areas; and 3) it has a non-structural characteristic which makes it difficult to estimate accurately [1]. The impact of drought can be categorized into three classes, including economical, environmental and social impacts which are briefly explained here. There are several economical impacts in the agriculture sector and other sectors such as forestry and fisheries that depend on surface and sub-surface water. In addition to direct impact of drought (losses in agricultural and livestock production), increasing water and wind erosion are some of the indirect effects of this natural disaster. Another impact of drought is increases in rangeland and forest fires which can put human and wildlife population in great risk. Numerous environmental impacts are resulted from the drought phenomenon including damages to plants, animals, water and air quality; loss of biodiversity; land degradation; increase in water and wind erosion and rangeland and forest fires. Some of these impacts have short-term effects and will return to previous conditions as the drought ends but some of them become permanent. Social impacts of drought can be related to decrease in life quality, public health and conflict between water consumers. One of the main social impacts is migration to urban areas. Most of the migrants barely return home after drought, as a result rural areas will lose valuable human resources.

To assess and monitor natural disasters including drought we need reliable and real time information. As drought occurs in large areas, using conventional methods to collect data for assessing and monitoring this disaster is limited. Remote sensing technology provides excellent possibilities in this field. The reason is that this technology is capable to collect data at local, regional and global scales rapidly and repetitively. Remotely sensed data can be used to study drought before, during and after disaster. As we know, the impact of drought can be reduced through our better understanding of drought and using some appropriate drought indices. Spectral indices appear to be more appropriate than conventional drought indices (e.g. Palmer Drought Severity Index) due to the timely and spatially continuous characteristics of remote sensing data. Most of the drought studies have used AVHRR sensor's data of NOAA satellite because it records land surface reflectance continuously (around 14 times a day) and is freely available. The aim of this paper is to introduce the most widely used remote sensing techniques such as the Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), Perpendicular Drought Index (PDI) and Modified Perpendicular Drought Index (MPDI) in drought studies.

Satellite-based drought indices

One of the major limitations of climate-based drought indices is their lack of spatial coverage and also they depend on data collected at weather stations which are sparsely distributed specially in arid lands which affects the reliability of these indices. Satellite-based drought indices have been widely used for assessing and monitoring different kinds of droughts (Meteorological drought, Hydrological drought, Agricultural drought and socio-economic drought). Some of the commonly used spectral indices will be briefly described below.

Normalized Difference Vegetation Index (NDVI)

Vegetation indices combine reflectance measurements from different portions of the electromagnetic spectrum to provide information about vegetation cover on the ground [2]. Healthy green vegetation has distinctive reflectance in the visible and near-infrared (NIR) regions of the spectrum. At visible and in particular red (R) wavelengths, plant pigments strongly absorb the energy for photosynthesis, whereas in the nearinfrared region, the energy is strongly reflected by the internal leaf structures. This strong contrast between red and near-infrared reflectance has formed the basis of many different vegetation indices. When applied to multispectral remote sensing images, these indices involve

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numeric combinations of the sensor bands that record land surface reflectance at various wavelengths. Pearson and Miller [3] first presented the near infrared/red ratio for separating green vegetation from soil background. Since then, numerous vegetation indices have been proposed, modified, analysed, compared and classified [4, 5, and 6]. The Normalized Difference Vegetation Index (NDVI) [7] has been used widely in many applications including regional and continental scales. The NDVI is defined by following formula:

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

It has been used for assessing and monitoring continental and regional land cover, vegetation classification, vegetation vigor and also for monitoring rainfall and drought, estimating net primary production of vegetation cover, crop growth condition and evapotranspiration in agriculture and natural environments [8]. According to previous studies, the NDVI vegetation index is directly related to vegetation vigor, density and growth, thus it can be used to identify variables that have inappropriate impacts on vegetation condition. It is clear that vegetation condition is a function of climate variables such as rainfall. Several studies have used the relationship between NDVI and rainfall data as an indicator of drought [9, 10]. The results of these studies show that there is a high relationship between NVDI values and rainfall data, thus this index can be used as an appropriate indicator of drought at regional and continental scales (Figure 1).

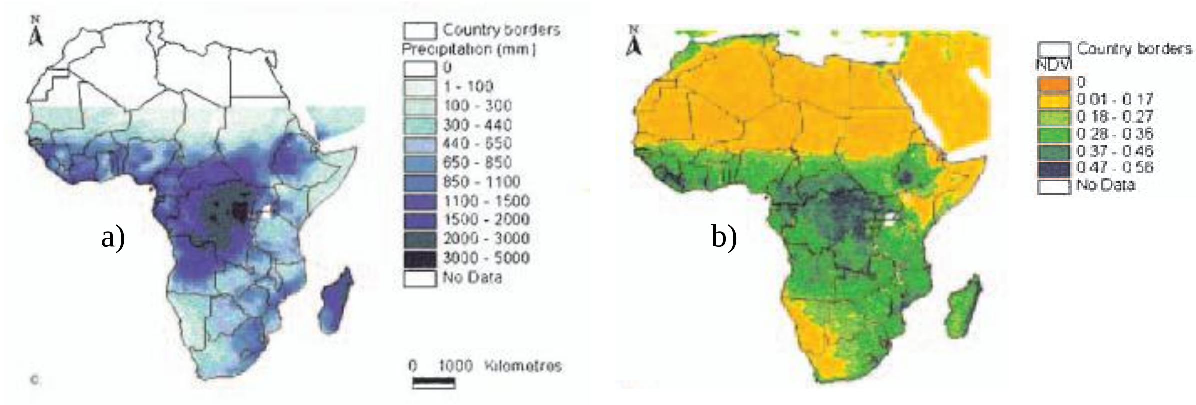

Figure 1- Comparison between rainfall data and the NDVI vegetation index [10]: a) rainfall map; and b) NDVI map

Vegetation Condition Index (VCI)

VCI is a NDVI-based vegetation index [11]. It is defined according to following formula:

$$VCI = \frac{NDVI - NDVI_{min,x}}{NDVI_{max,x} - NDVI_{min,x}} \times 100$$

(2)

Where NDVI is the vegetation index, $NDVI_{min,x}$ is the minimum NDVI recorded during month x and $NDVI_{max,x}$ is the maximum NDVI recorded during month x. The VCI values between 50-100% indicate normal condition whereas values around zero indicate sever drought condition. The VCI has successfully been used for drought assessment and monitoring in different regions such as the southern Great Plains (USA), Mediterranean region and Asia [9, 12].

Temperature Condition Index (TCI)

This index was proposed by Kogan [13]. TCI is based on the thermal band of AVHRR sensor which is converted to Brightness Temperature (BT). This index is used to determine the effect of temperature on vegetation cover. TCI is a simple method and it only needs time series of day time thermal remote sensing data. However, the calibration of this data is necessary because air temperature, net radiation, wind speed and humidity affect daytime thermal measurements. TCI formula is similar to the VCI and is defined as below:

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$$TCI = \frac{BT_{max} - BT}{BT_{max} - BT_{min}} \times 100 \quad (3)$$

Where BT is brightness temperature, BTmin, is the minimum BT recorded during specific period and BTmax, is the maximum BT recorded during specific period. Research has shown that the TCI is a suitable index for detecting drought patterns [e.g. 14].

Perpendicular Drought Index (PDI)

This index seems to be a suitable index in arid environments. Because it relies on not only vegetation cover but also bare soil surfaces. The PDI like other perpendicular vegetation indices [15] uses a soil line with vegetation cover estimated by the perpendicular distance from it in bi-spectral space. As the designer of this drought index [16] has explained, the PDI is a very applicable method for drought detection in low vegetated regions. The VCI is defined according to following formula:

$$PDI = \frac{1}{\sqrt{M^2+1}}(R_{Red} + MR_{NIR}) \quad (4)$$

Where, RRed and RNIR refer to the reflectance of Red and NIR bands and M is the slope of soil line. Despite the usefulness of the PDI in drought detection, this index appears to have limitations when land surface varies from very low to very high vegetation cover in agricultural lands and also is less accurate in topographic regions. To reduce these limitations a modified index called Modified Perpendicular Drought Index (MPDI) was proposed [17]. The results of this study [17] showed that the MPDI is less sensitive to vegetation density and topographic features and shows drought patterns more accurate than the PDI index (Figure 2). MPDI is defined according to following formula:

$$MPDI = \frac{R_{Red} + MR_{NIR} - f_v(R_{v,Red} + MR_{v,NIR})}{(1-f_v)\sqrt{M^2+1}} \quad (5)$$

Where, Rv,Red and Rv,NIR are vegetation reflectance in Red and NIR bands. According to field measurements for known vegetation growth these parameters are 0.05 and 0.5 respectively, while fv is the vegetation fraction (100% vegetation cover=fv=1 and bare soil=fv=0).

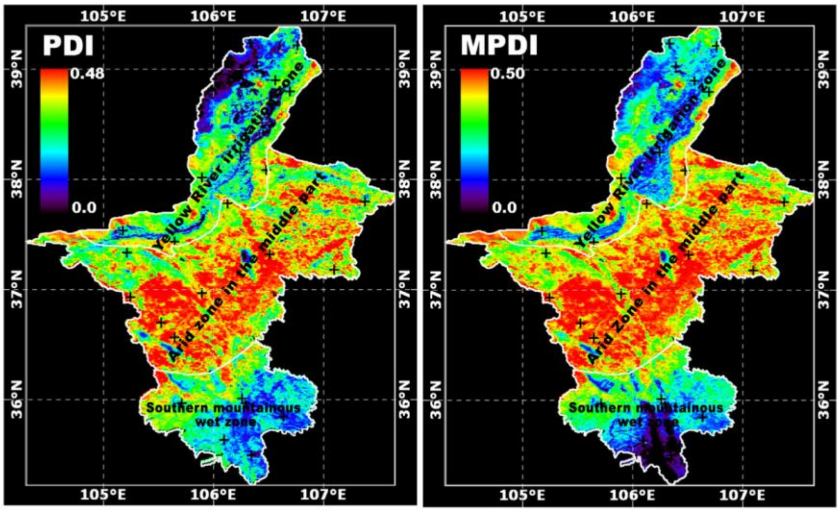

Figure 2- Comparison between PDI and MPDI for detecting drought

Conclusions

Usually, more attention is given to environmental disasters such as food management than drought management. In last few years, sever drought has been occurred in most of the arid environments including Iran. With increasing population in this region pressure on all types of water resources will be intensified especially in water-short years. Therefore, it is imperative for government and non-government organizations to improve their approaches in managing water sources in drought period.

Due to harsh condition and broadness of arid areas we need methods that can provide information for entire area rather than local stations. Remote sensing technology appears to be a useful tool in this

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field. It can provide real-time and spatially continuous data that is necessary for drought management. Among the remotely-sensed derived indices described here, NDVI has been widely and successfully used in drought assessment and monitoring at regional and continental scales. This approach has also been applied to the northwest region of Iran [9] and the results are promising. Therefore, for a cost-effective, accurate and real-time drought management we need to integrate remote sensing approaches in our research and projects.

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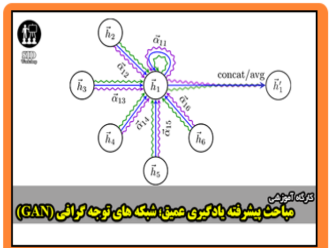

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