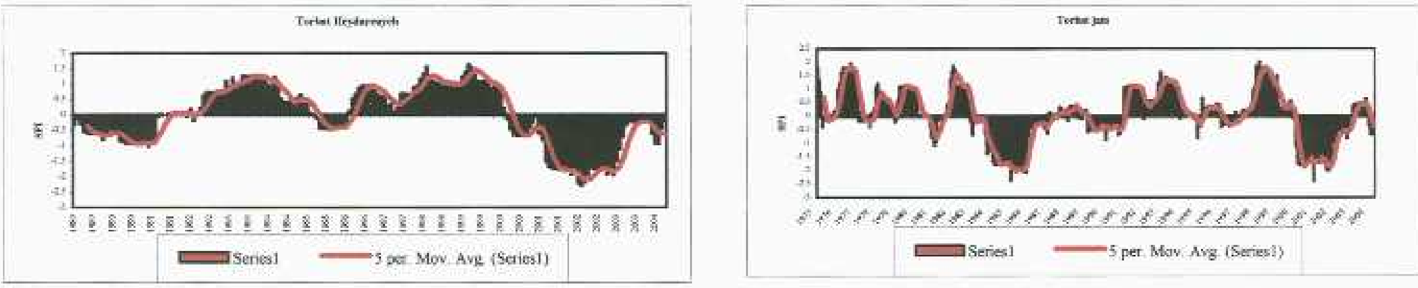

Figure 6 Twenty four-month SPI values for selected station in North-East of I. R. Iran. *Source CRI, 2004*

conditions that were standardized so that comparisons using the index could be made between locations and between months. The PDSI is a meteorological drought index, and it responds to weather conditions that have been abnormally dry or abnormally wet. When conditions change from dry to normal or wet, for example, the drought measured by the PDSI ends without taking into account streamflow, lake and reservoir levels, and other longer-term hydrologic impacts. The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content (AWC) of the soil. From the inputs, all the basic terms of the water balance equation can be determined, including evapotranspiration, soil recharge, runoff, and moisture loss from the surface layer.

The Palmer Index is popular and has been widely used for a variety of applications around the world. It is most effective measuring impacts sensitive to soil moisture conditions, such as agriculture. It has also been useful as a drought-monitoring tool and has been used to trigger actions associated with drought contingency plans. The map of soil moisture and calculation of the PDSI for some points in north-east of Iran are shown in Figures 7-9. Figure 10 shows the sample calculation of the PDSI for Golmakan station located at north part of Khorasan Prefecture.

There is an immediate operational need to keep track of drought conditions and environmental changes for the purpose of monitoring and predicting the production of the rangelands and marginal agricultural areas, whether they be the result of shifting climatic zones, human actions or a combination of these. Assessing risk of drought is a first step in this direction. Closer attention can then be paid to areas and population groups identified as most at risk. Whether the desert is expanding or not, there is agreement that patterns of vegetative cover in all areas of the I. R. Iran are dependent

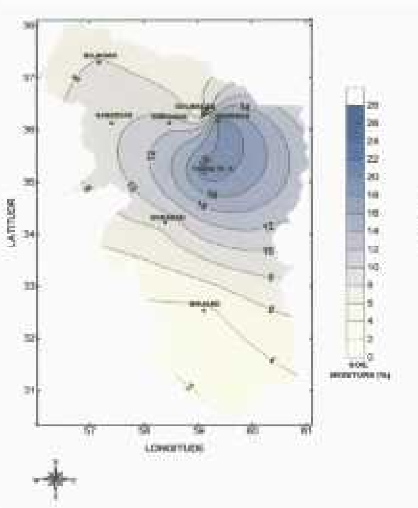

Figure 7: Map of soil moisture contour in Khorasan province in 30 cm (January 2002), *Source: CRI, 2002*

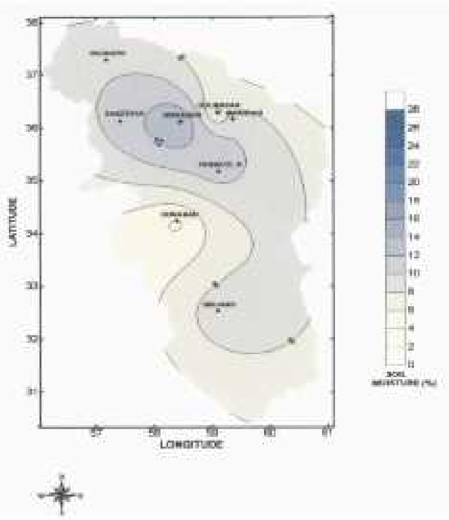

Figure 8: Map of soil moisture contour in Khorasan province in 30 cm (April 2002), *Source: CRI, 2002*

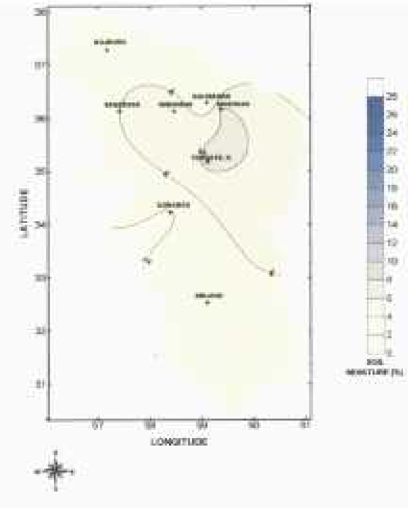

Figure 9 Map of soil moisture contour in Khorasan province in 30 cm (Jun 2002). *Source: CRI, 2002*

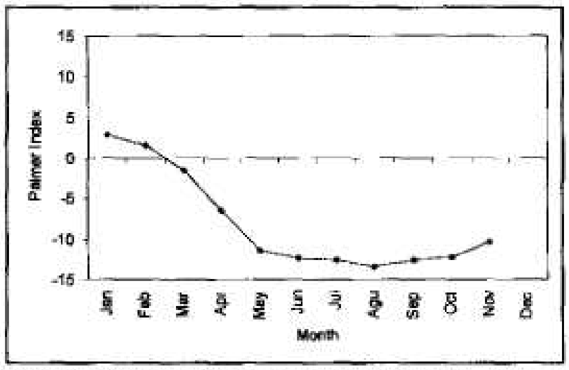

Figure 10. PDSI for Golmakan Station in Khorasan province for 2001. *Source CRI, 2002*

on rainfall, with the exception of some irrigated areas. In most of the areas, rainfall is the key limiting factor in crop and rangelands production. Increasingly dense and accurate rainfall observations that can be analyzed in real time are required to monitor closely the progression of the cropping season. This is because in areas such as the I. R. Iran, great spatial and temporal variability of rainfall mean that interpolating between raingage values to obtain estimates of the rainfall at a particular point can give rise to serious errors. Proper monitoring for this region therefore requires an impractically large number of gauges. Even if such dense coverage were possible, the rainfall data on its own is insufficient to draw useful information regarding the status of the crop. In the regard of environmental changes monitoring, very little data exists in all areas of I. R. Iran, which can be used to measure trends in land degradation or desertification. Instead proxy measures, such as vegetation cover or crop yields, have to be used. Vegetation in areas at risk will show moisture stress that then results in changes in vegetation cover. Information on vegetation cover can in turn be used as a first cut indicator of the possible occurrence of drought, although additional indicators will also be required to carry out a full drought assessment, since the causes and consequences of drought are multi-faceted.

Vegetation studies based on remotely sensed data began to be used in the mid-1970s with data obtained from Landsat MSS (MultiSpectral Scanner). Today the application of remote sensed data in vegetation studies is widely operational. The increasing use of satellite remote sensing for civilian use has proved to be the most cost effective means of mapping and monitoring environmental changes in terms of vegetation, rainfall and non-renewable resources. Mapping and modeling environmental changes as they progress can be achieved by integrating digital datasets obtained by remote sensors with relevant ground information. There is a particular need to improve and harmonies data from meteorological satellites such as NOAA and METEOSAT, in order to produce standard, compatible outputs which can be used to aid decision-making in agricultural warning and forecasting, in particular by estimating rainfall and plant activity. Another problem is the need to improve assessments of soil degradation at all levels, from the global to the local. This could be accomplished by combining remote-sensing information from satellites, such as LANDSAT or SPOT, with data from ground observation sites.

The methodology, which is employed during recent years in our country, is based on the relationship between remote sensed data about vegetation, in the form of vegetation index, and rainfall. The main application of vegetation indices is the monitoring of vegetation conditions. Vegetation indices (VIs) are functions of the spectral contrast between the reflected Near Infrared (NIR) and Visible (VIS) radiance from a given surface. This contrast is greater for vegetation than for soil, and hence the higher the vegetation index the denser the cover and vigor of vegetation. Although there are many new indices that are theoretically more reliable than the NDVI (such as soil-adjusted, transformed soil-adjusted, atmospherically resistant, and global environment monitoring indices), they are not yet widely used with satellite data. The most widely used index is the NDVI, the Normalized Difference Vegetation Index, using AVHRR (Advanced Very High Resolution Radiometer) data. The relationship of NDVI to rainfall is used as a basis for employing NDVI as an indicator of drought in I. R. Iran. The research examines the implications of the results for operational drought risk monitoring. Based on the obtained results, the study stresses the need for the use of remote sensing to provide real time data for forecasting. This study also concludes that remote sensing is the only feasible data source for requirement recourses for the information system necessary for drought monitoring.

Using Remote Sensing for Drought Monitoring

Remote sensing is the acquisition of digital data in the reflective, thermal or microwave portions of the electromagnetic spectrum (EMS). Due to large spatial extent of drought in many areas in the world, scientists will focus on data gathered from satellite remote sensing system. There are many sensors on board numerous satellites, which can be used to assist prediction of drought decision-making process.

Remote sensing of the surface occurs at wavelengths of the EMS where light can pass through the earth's atmosphere with no, or little interaction.

One of the best methods to distinguish of drought conditions is the vegetation monitoring with reflective remote sensing. The reflective of the EMS ranges normally form 0.4 to 3.75 mm. Some of indices are defined for vegetation monitoring such as NDVI, VCI, MVCI, and MVCD.

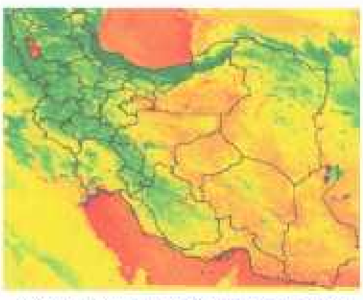

Figure 11: NDVI images in 1998

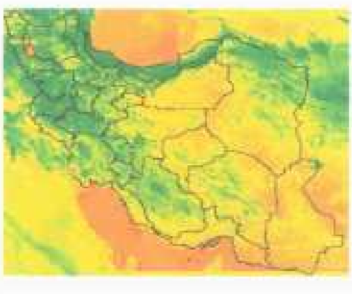

Figure 12: NDVI images in 1999

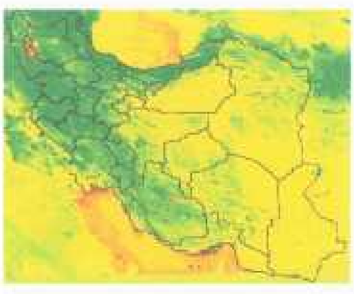

Figure 13: NDVI images in 2000

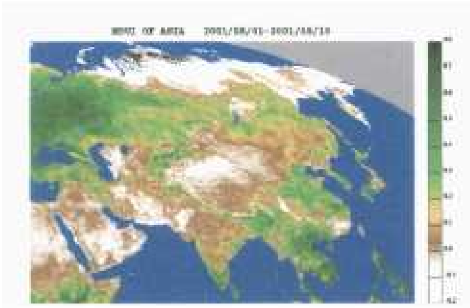

Figure 14: NDVI images in 2001/05/1-10

Figure 15: NDVI images in 2001/05/11-20

Figure 16: NDVI images in 2001/06/1-10

Figure 17: NDVI images in 2001/06/11-20

Figure 18: NDVI images in 2001/06/21-30

Remote Sensing of Vegetation Status

During periods of drought conditions, physiologic changes within vegetation become apparent. Satellite sensors are capable of discerning many such changes through spectral radiance measurements and manipulation of this information into vegetation indices. Such indices are also sensitive to the changes in vegetation affected by moisture stress.

The visible (VIS) and near infrared (NIR) bands on the satellite multispectral sensors allow monitoring of the greenness of vegetation. Stressed vegetation is less reflective in the near IR channel than nonstressed vegetation and also absorbs less energy in the visible band. Thus the discrimination between moisture stressed and normal crops in these wavelength is most suitable for monitoring the impact of drought on vegetation.

The NDVI is defined as;

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - VIS}{\mathrm{NIR} + VIS}$$

Where NIR and VIS are measured condition in near infrared and visible (chlorophyll absorption) bands.

The NDVI varies with the magnitude of green foliage (green leaf area index, green biomass, or percentage green foliage ground cover) brought about by phonological changes or environmental stresses. The temporal pattern of NDVI is useful in diagnosing vegetation condition.

In this research for means of drought conditions monitoring we used the reflective vegetation indices base on NDVI. Also for long term vegetation condition monitoring we must use some other indices such as VCI.

Indeed the VCI may be thought of as being closely related to the vegetation condition in a specific region. The primary aim of developing the VCI was to assess change in the NDVI signal through time due to weather conditions, by reducing the influence of geographic or ecosystem variables, meaning climate, soils, vegetation type and topography (Kogan 1995).

AVHRR-Based Algorithm

The VCI and TCI were derived from NDVI and Ch4 radiance, respectively. The latter was converted to brightness temperature (BT). The condition of vegetation (VCI and TCI) for a particular year could be calculated from the NDVI and BT values. Since the NDVI and BT interpret extreme weather events in an opposite manner (for example, in case of drought, the NDVI is low and BT is high, conversely, in a non drought year, the NDVI is high while the BT is low) (Das 2000).

The VCI and TCI approximate the weather components in NDVI and BT Values. They change from 0 to 100, reflecting variation in vegetation conditions from extremely poor to optimal. In drought years leading to yield reduction, VCI and TCI values drop below 35 (Kogan 1995 and 1997).

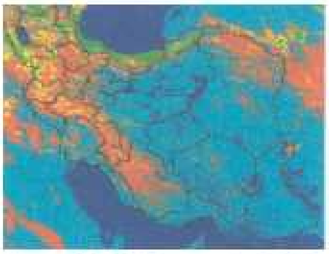

Figure 19 VCI images in 1998

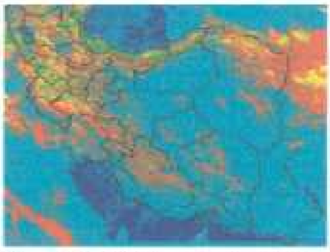

Figure 20 VCI images in 1999

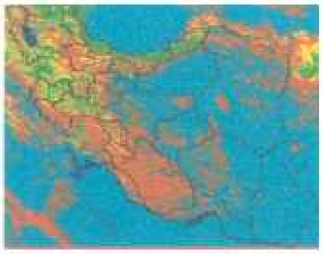

Figure 21: VCI images in 2000

An assumption in the calculation of the VCI is that reliable, calibrated AVHRR data be used to form the NDVI. The Vegetation condition index(VCI) and TCI proposed by Kogan (1990) is defined as:

$$VCI = \text{١٠٠} \times \frac{\mathrm{NDVI} - \mathrm{NDVI}_{min}}{\mathrm{NDVI}_{max} - \mathrm{NDVI}_{min}}$$

$$TCI = \text{١٠٠} \times \frac{(\mathrm{BT}_{max} - BT)}{\mathrm{BT}_{max} - BT_{min}}$$

Liu and Kogan (1996) defined drought in the four ways:

1) Monthly rainfall less than 50 mm

2) NDVI value lower than 0.18

3) Monthly rainfall departure lower than 50%of the mean and 50 mm lower than the mean value

4) VCI lower than 36%

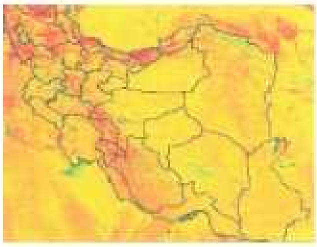

Figure 22: MVCD images between 1998 and 1999

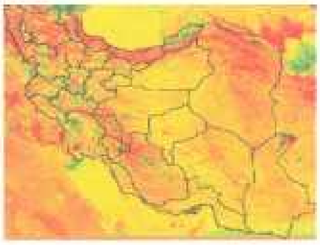

Figure 23: MVCD images between 1998 and 2000

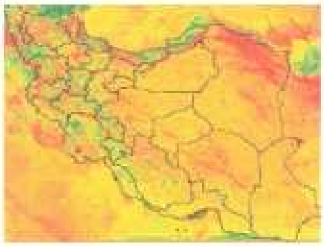

Figure 24: MVCD images between 1999 and 2000

Results and Discussions

In this research the following steps have been carried out.

Step 1: We have got NOAA satellite images in AVHRR format for 1998-2002, monthly from Iranian Remote Sensing Center (IRSC).

Step 2: For application of this images some image processing softwar's such as IDRIS, ERMAPPER, ENVI, and ILWIS have been used.

Step 3: After initial and secondary correction contain radiometric and geometric correction, the NDVI have been calculated for each images.

Step 4: In this step for all of 12 calculated monthly NDVI, VCI's, the annually for each 5 years have been derived.

Step 5: In this final step for two continuous images, MVCD is calculated.

Concluding Remarks:

We could conclude from NDVI, VCI during 1998-2000 and MVCD for 1998-1999, 1999-2000, 1998-2000 the following items,

-Most eastern, south and central regions of the country,

vegetation condition has been derived in 2000 as well as 1998, which indicates that the continuous drought condition in most regions of Iran.

-The MVCD images from 1998 to 2000 shows the considerable variation in vegetation in north of Iran.

-The sever drought has been occurred in more than 18 Provinces of the country, where the Khorasan, Kerman, Khuzestan and Esfahan provinces have experienced extreme Drought condition.