

United Nations/Islamic Republic of Iran Workshop on the

Space Technology Applications
for **Drought**, **Flood** and **Water**
Resources Management

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Drought Monitoring in Iran Using Remote Sensing Data

Saeid Hamzeh

Associate Professors of Remote Sensing and GIS, Faculty of Geography,

University of Tehran, Iran

Email: saeid.hamzeh@ut.ac.ir





Drought

- Drought is a prolonged dry period in the natural climate cycle that can occur anywhere in the world (WHO).
- It is a normal, recurring feature of climate and slow-onset disaster which is characterized by the lack of precipitation, with different characteristics and impacts from region to region.



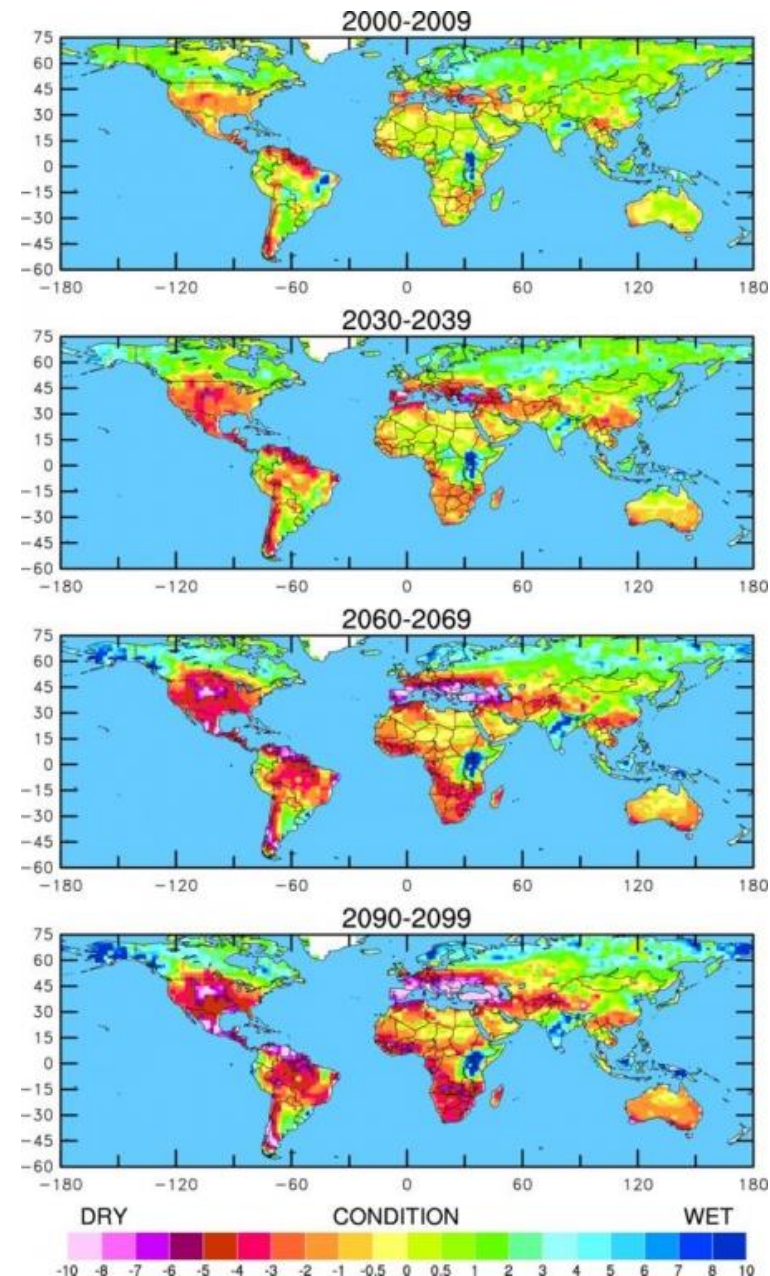
Operational definitions of drought

- Meteorological drought (precipitation deficiency)
- Agricultural drought (deficit of soil moisture or decreasing crop production)
- Hydrological drought (deficit in water suppliers at basin scale)
- Socioeconomic drought (affect people and food supply)

Increase the Risk of Drought under Global Warming

Global warming associated with climate change will likely create increasingly dry conditions across much of the globe in the next years. And most part of the world, specially arid and semi-arid regions (such as Iran) will face a growing threat of severe and prolonged drought in coming decades (NCAR, 2010).

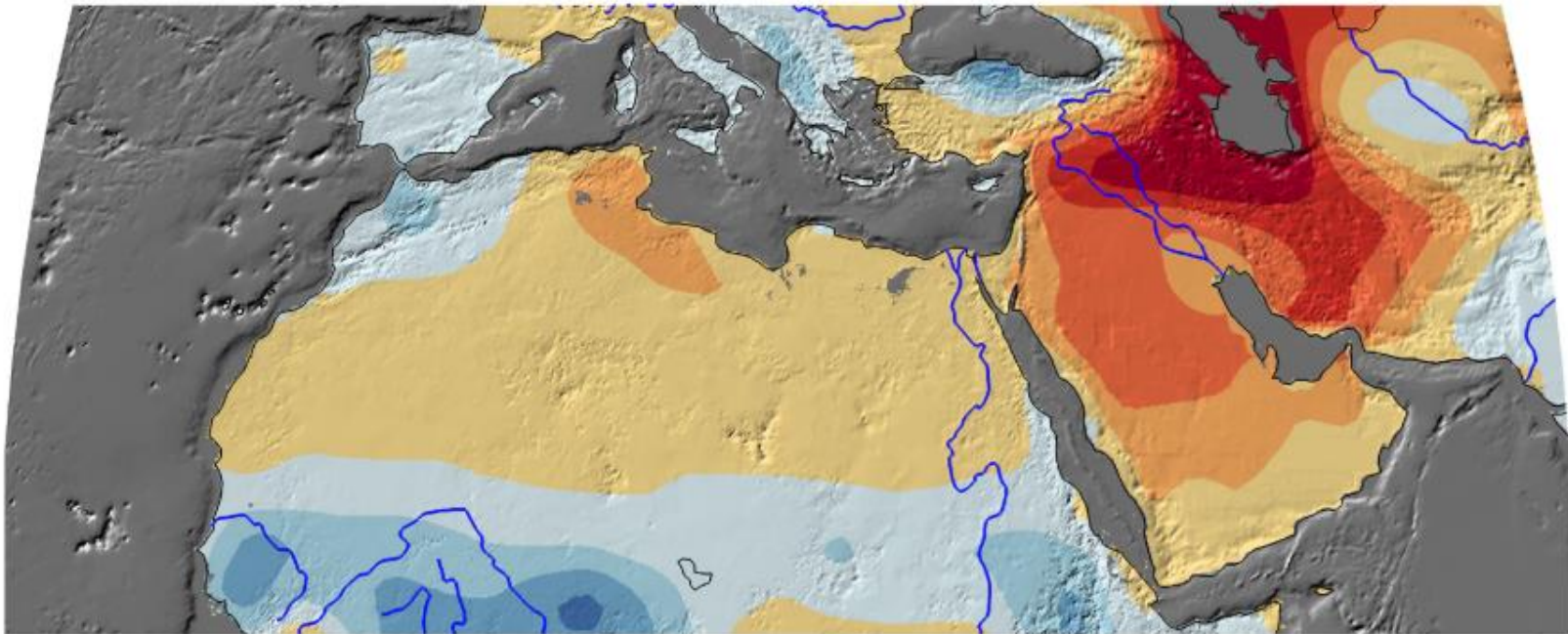
These maps shows the potential for future drought worldwide for the years 2000 to 2099, based on the current projections of future greenhouse gas emissions. Source: Adapted from [Dai \(2011\)](#).



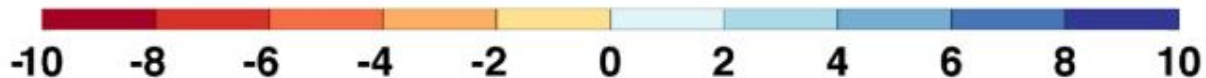


Cumulative Total Freshwater Losses in Middle East/North Africa as Seen by NASA's GRACE, 2002-15

GRACE TWS trends: increases & decreases over 13 years (2002-2015)

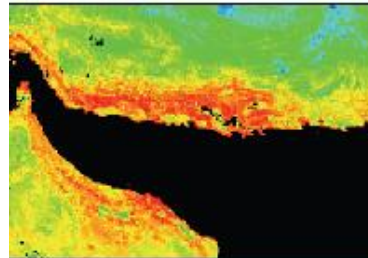


Inches in water

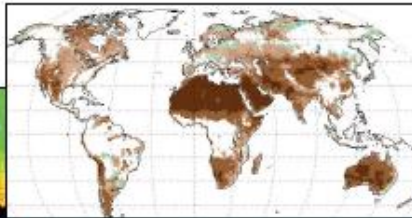




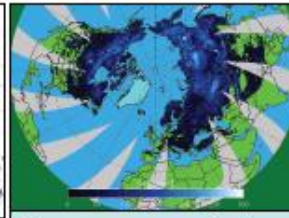
Remotely Sensed Data for Water Resources Management and Drought Monitoring



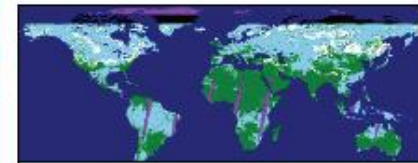
Land surface temperature
(MODIS, AVHRR, GOES, ...)



Surface soil moisture
(SMMR, TRMM, AMSR-E,
SMOS, Aquarius, SMAP)



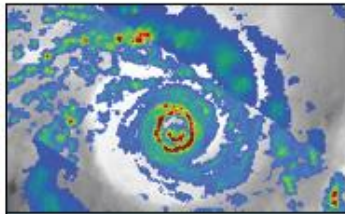
Snow water equivalent
(AMSR-E, SSM/I,
SCLP)



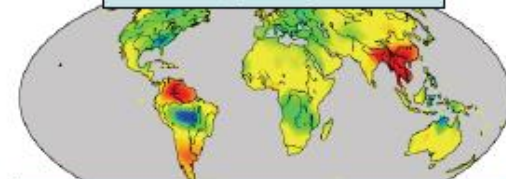
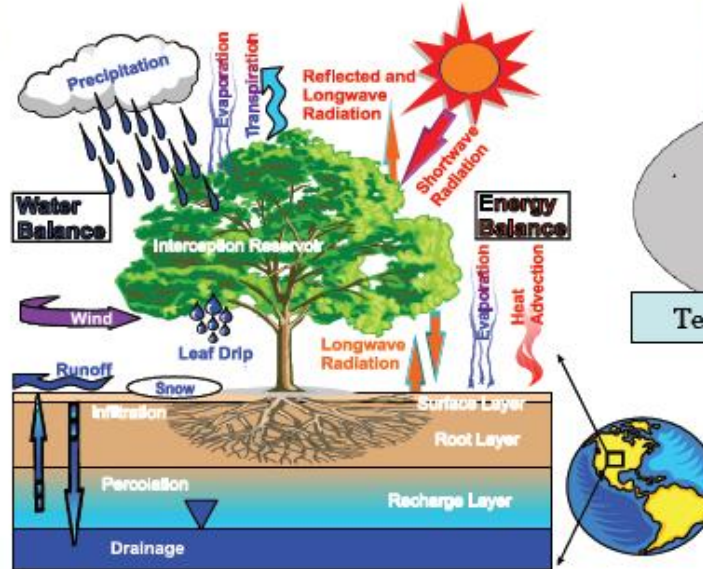
Snow cover fraction
(MODIS, VIIRS, MIS)



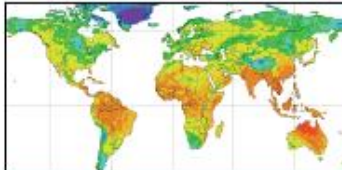
Water surface elevation
(SWOT)



Precipitation
(TRMM, GPM)



Terrestrial water storage (GRACE)



Radiation
(CERES, CLARREO)



Vegetation/Carbon
(AVHRR, MODIS, DESDynI,
*ICESat-II, HypIRI, LIST,
ASCENDS*)

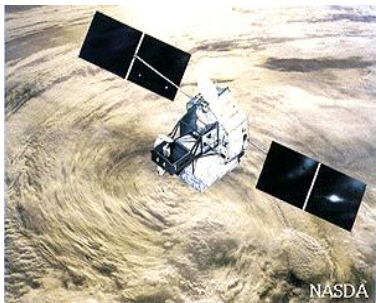
Satellite observations



Remote Sensing for Drought Monitoring

Over the past two decades, numerous satellite-based indices (such as NDVI, SMDI, VCI, TCI, VHI, PCI, OVDI, etc.) have been developed for regional drought assessment. Capability of these indices to spatiotemporal monitoring of drought in different regions around the world has been well documented.

Satellite Based Indicators for Drought Monitoring



Vegetation Cover (NDVI, VCI, VHI...)

Biomass (LAI, Crop Yield)

Evapotranspiration

Soil Moisture

Precipitation (SPI)

Land Surface Temperature (LST, TCI, ..)



Objectives of this research

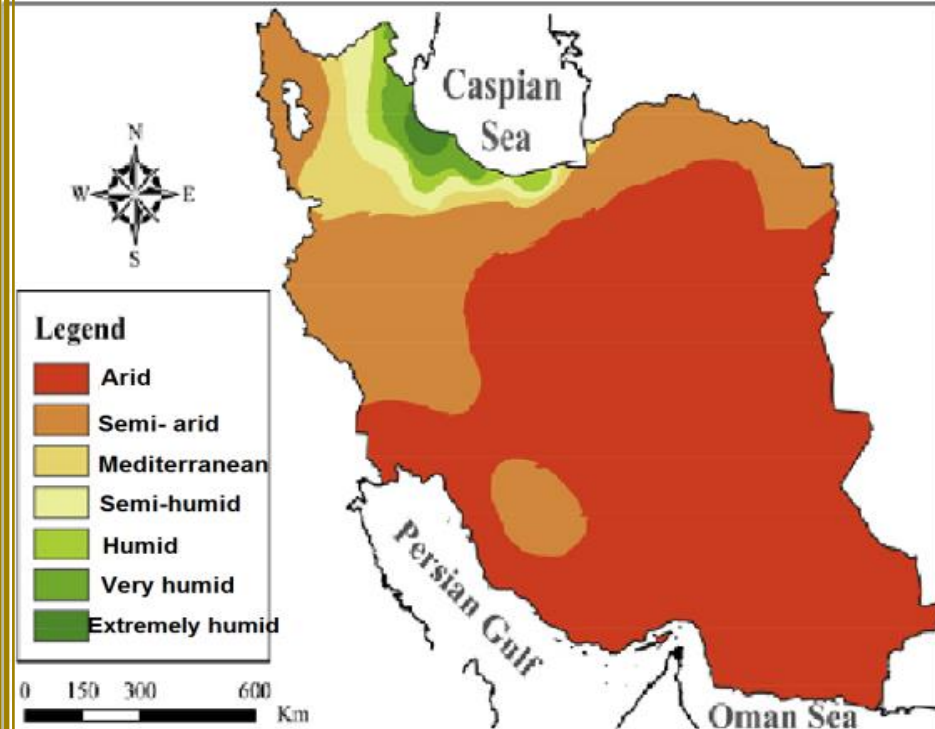
- To assess the performance of remote sensing-based indices for drought monitoring in Iran.
- Study the relationship (and lag time) between agricultural and meteorological droughts in Iran.
- Exploring the best indices for agricultural drought monitoring and assessment in different region of Iran.

Climate of Iran



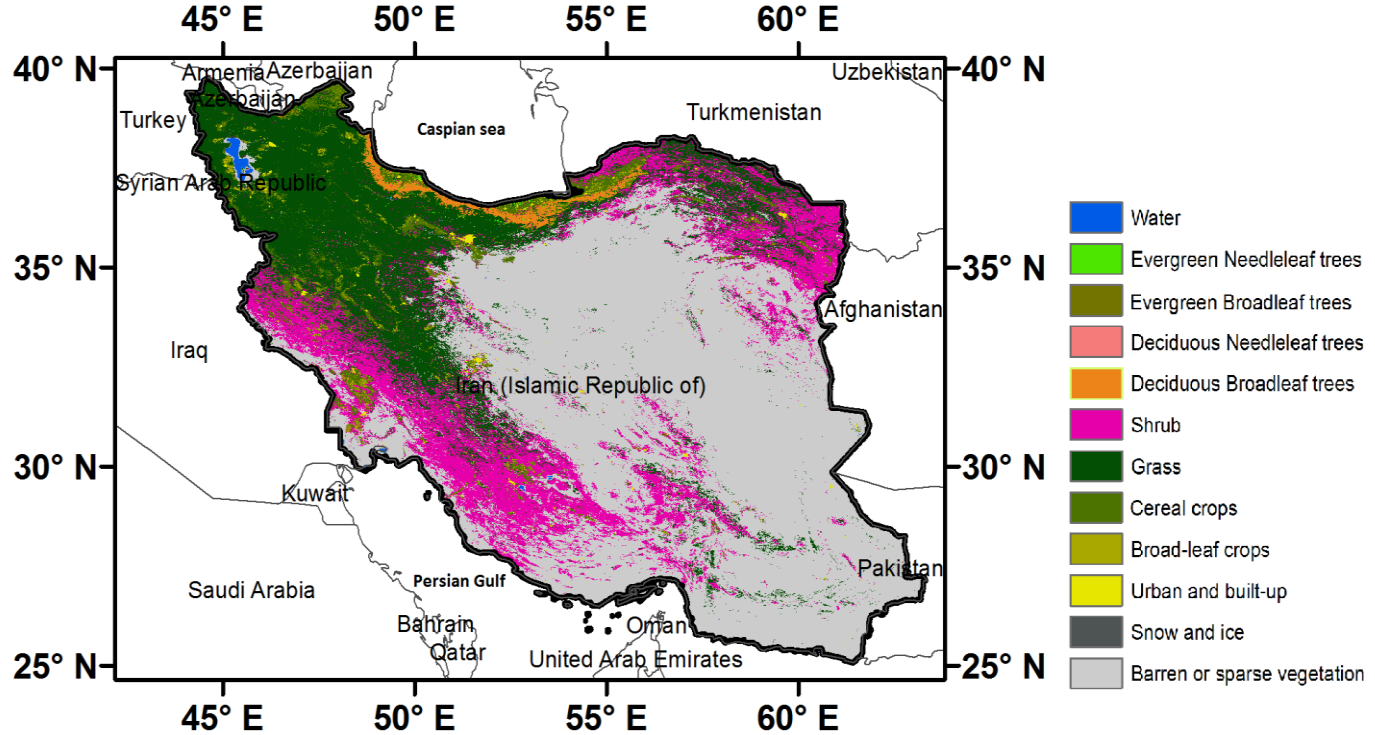
- Area: **165 million ha**
- Population: **80 million**
- from 10 millions in 1920 to more than 80 millions in 2018 (about 8 times)
- Average Rainfall: **250 mm**
- Climate: Iran has 7 climatic zones varying from Arid to Extremely humid.

Most part of Iran is classified among the arid and semi-arid region



The climate classification of Iran based on De Martonne climate type (1966- 2005) (Tabari *et al.*, 2014)

Land Cover of Iran



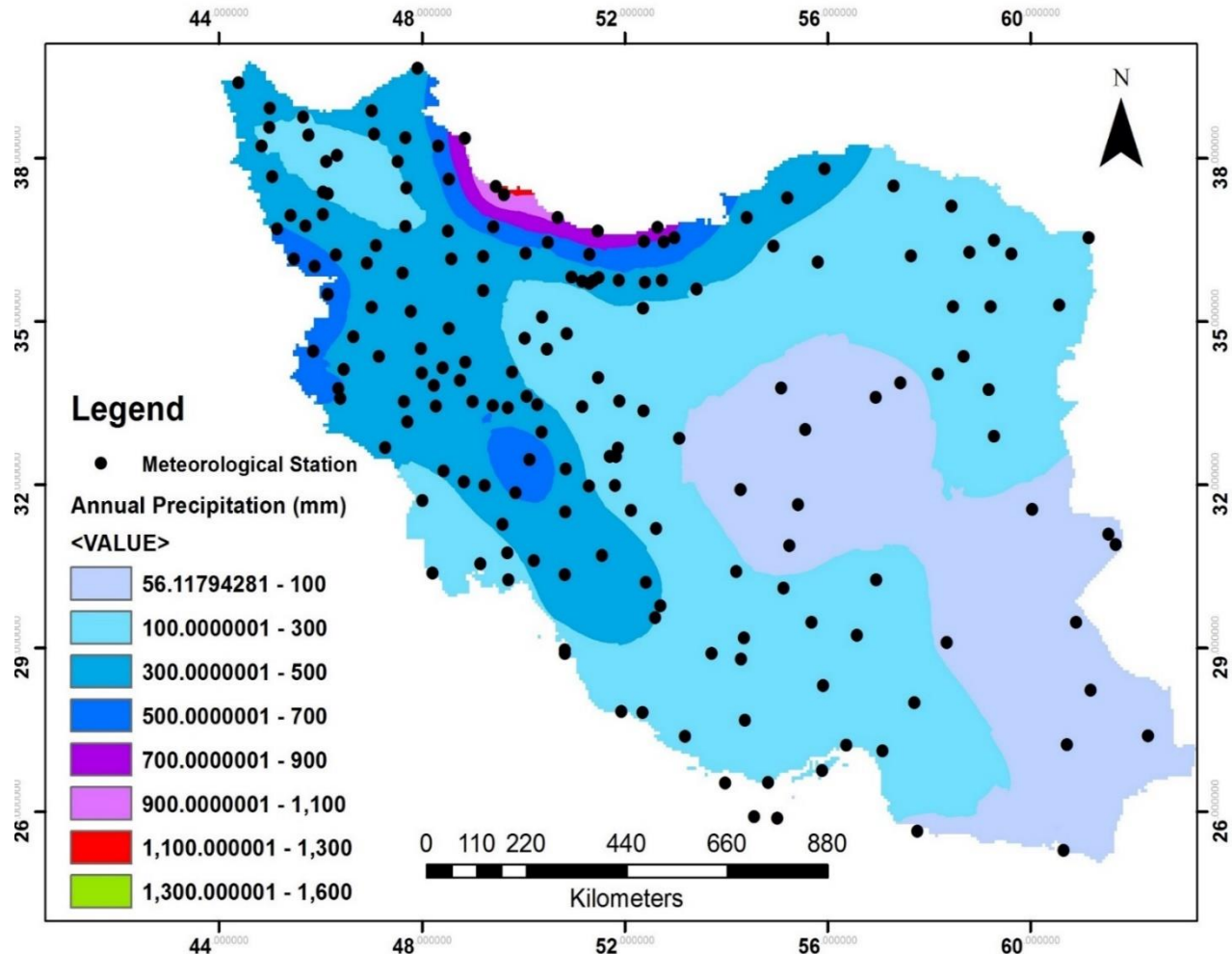
MCD12Q1
Land Cover Type

• Total land area of the country :	165 Mha
• Cultivable area :	37 Mha
• Actual cultivated area :	19 Mha
• Forests area:	12.4 Mha
• Pastures, mountains and deserts area:	89.2 Mha
• Irrigated area:	8 Mha
• Rain-fed land area:	6 Mha
• under surface irrigation:	7.6 Mha (95%)
• under the pressurized irrigation:	0.4 Mha (5%)

In-situ Precipitation Data

Monthly precipitation data of 153 observation stations for the period of 2000 till 2015 were used in this study.

The average annual precipitation is 250 mm and the range (varies from 50 mm to more than 1600 mm)



Location of meteorological stations and classified map of annual precipitation over Iran

Meteorological Drought Monitoring

- The Standardized Precipitation Index (SPI) which is the widely used drought index was selected as a meteorological drought index. This index is only based on precipitation data and defined as following by McKee et al. (1993, 1995)

$$SPI = (P_i - P) / S$$

Classification of SPI value (McKee et al,1993)

SPI Value	Drought Class
2.0+	extremely wet
1.5 to 1.99	very wet
1.0 to 1.49	moderately wet
-.99 to .99	near normal
-1.0 to -1.49	moderately dry
-1.5 to -1.99	severely dry
-2 and less	extremely dry

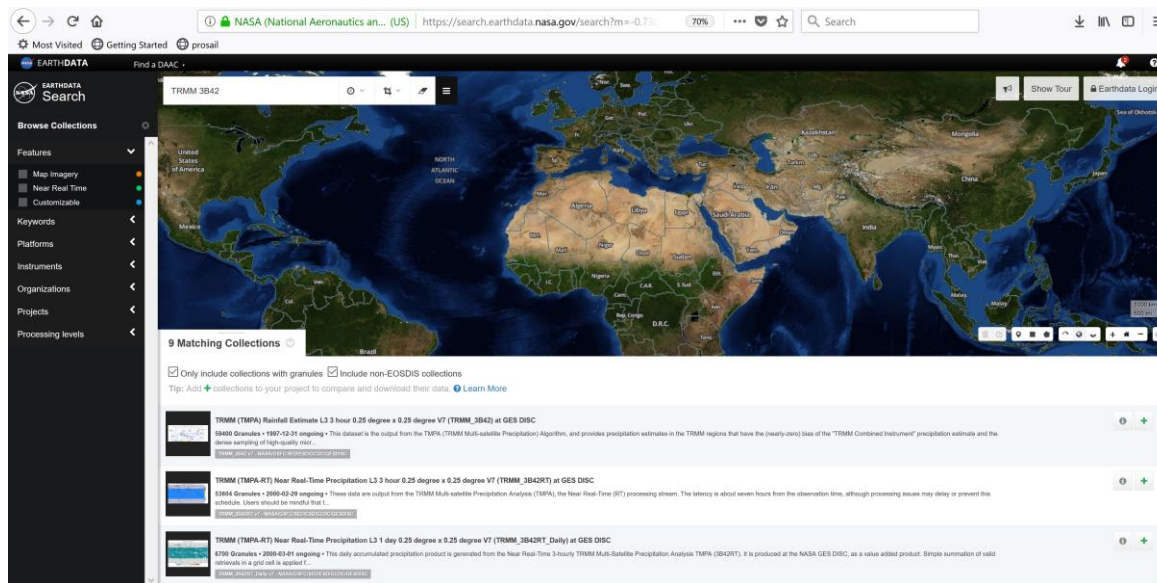
- Different time scales of SPI (accumulated 3, 6, 9,12-month SPI data) were calculated for the ground and TRMM precipitation data during 2000–2015.

Remote Sensing Data



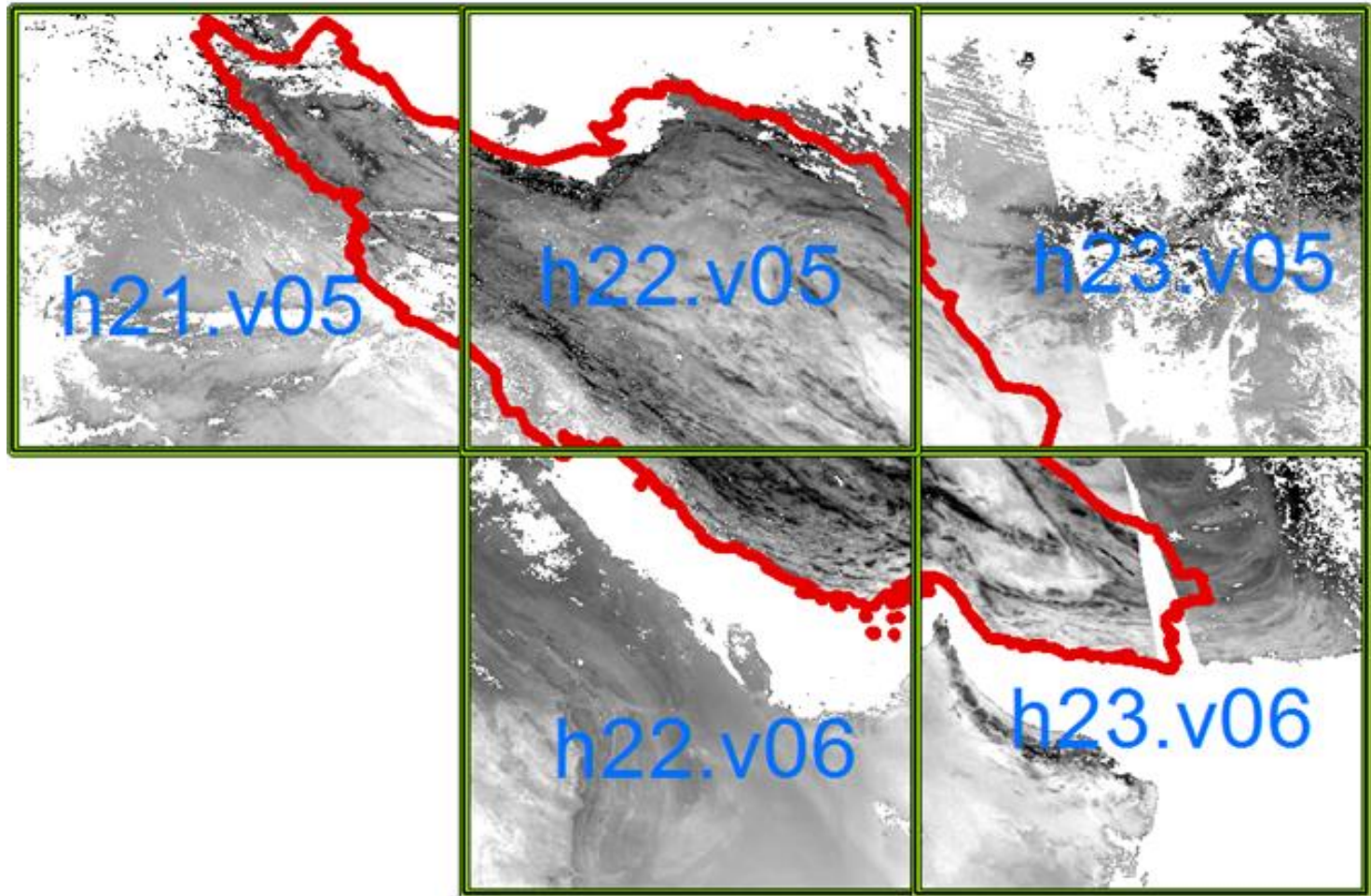
- **TRMM 3B42** : Daily Precipitation data
- **MOD11A2** : Eight-day LST data with 1-km resolution
- **MOD13A2**: 16-Day MODIS/Terra Vegetation Indices 1km
- **MCD12Q1**: Land Cover Type

These data were downloaded from The Earth Observing System Data and Information System (EOSDIS) <https://earthdata.nasa.gov>



The screenshot shows the EarthData Search interface. The search bar contains "TRMM 3B42". The main map area displays a global map with a search box at the top. Below the map, there are 9 matching collections. The first collection is "TRMM (TMPA) Rainfall Estimate L3 3 hour 0.25 degree x 0.25 degree V7 (TRMM_3B42) at GES DISC". The second collection is "TRMM (TMPA-RT) Near Real-Time Precipitation L3 3 hour 0.25 degree x 0.25 degree V7 (TRMM_3B42RT) at GES DISC". The third collection is "TRMM (TMPA-RT) Near Real-Time Precipitation L3 1 day 0.25 degree x 0.25 degree V7 (TRMM_3B42RT_Daily) at GES DISC".

Five tiles of MODIS data (h21v05, h22.V05 , h23.V05 , h22.V06 , h23.V06) were used to cover Iran



Sinusoidal Projection Map



Remote sensing Drought Indices:

- Vegetation Condition Index (VCI)
- Thermal Condition Index (TCI)
- Vegetation Health Index (VHI)
- Temperature Vegetation Dryness Index (TVDI)

These indices have successfully applied for numerous case studies in many different environmental conditions around the globe.



Vegetation condition Index (VCI)

The VCI (Kogan, 1994) is derived from the Normalized Difference Vegetation Index (NDVI). It is a scaling of the NDVI between its maximum and minimum value, and can be expressed as:

$$VCI_j = \frac{NDVI_j - NDVI_{min}}{NDVI_{max} - NDVI_{min}} * 100\%$$

- VCI_j is the image of vegetation condition index values for date j;
- $NDVI_j$ is the image of NDVI values for date j;
- $NDVI_{max}$ and $NDVI_{min}$ are images of maximum and minimum NDVI values from all images within the data set;
- VCI assesses changes in the NDVI signal through time due to weather conditions, reducing the influence of ‘geographic’ or ‘ecosystem’ variables i.e. climate, soils, vegetation type and topography (Kogan, 1995c).



Thermal condition Index (TCI)

The TCI algorithm is similar to VCI, but relates to the Land Surface Temperature (LST) estimated from the thermal infrared bands.

$$TCI = \frac{LST_{\max} - LST}{LST_{\max} - LST_{\min}}$$

Where LST, LST_{max} and LST_{min} are the values of LST, maximum LST and minimum LST of each pixel respectively in same month during the study period.









Vegetation Health Index (VHI)

VHI is a composite index joining the Vegetation Condition Index (VCI) and the Temperature Condition Index (TCI).

$$VHI = 0.5(VCI) + 0.5(TCI)$$

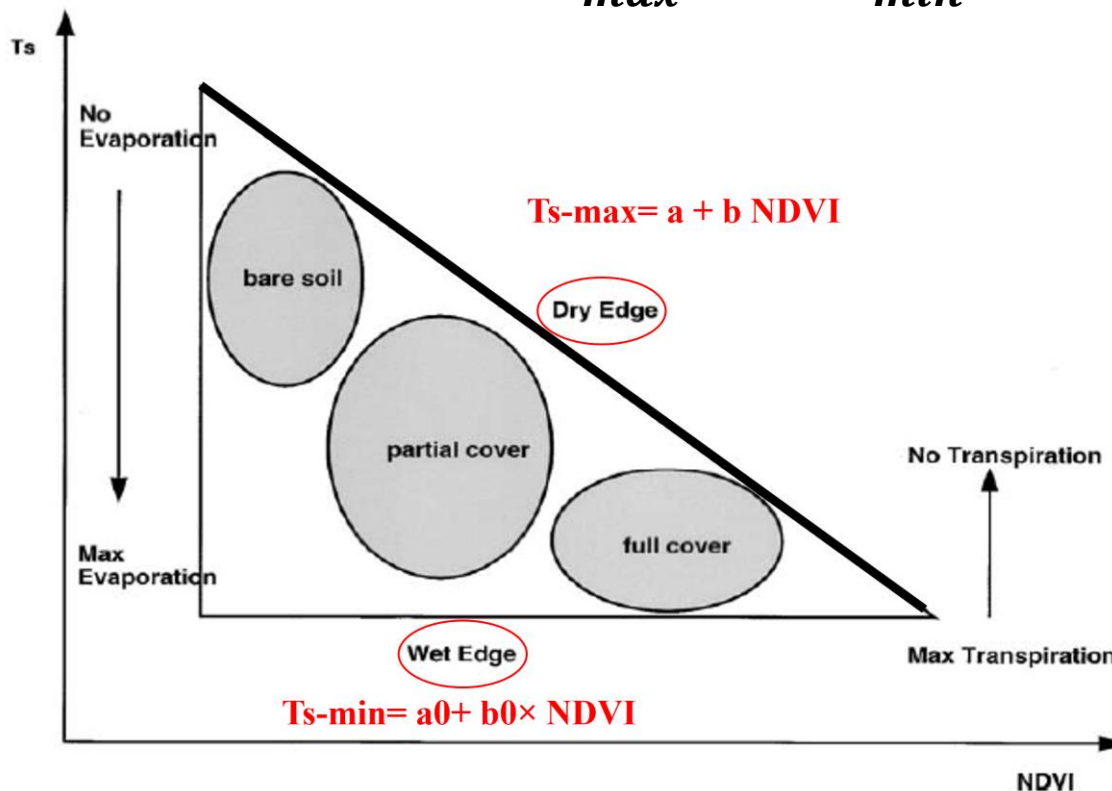
For each pixel and individual year, the average of monthly VHI values between the beginning of April till end of September were averaged to obtain a representative value of VHI for the drought-sensitive part of the crop season.

Drought Classes	VHI
Extreme Drought	 <10
Severe Drought	 10-20
Moderate Drought	 20 - 30
Pre Drought	 30 - 40
Near Normal	 40 - 50
No Drought	 50<

Temperature Vegetation Dryness Index (TVDI)

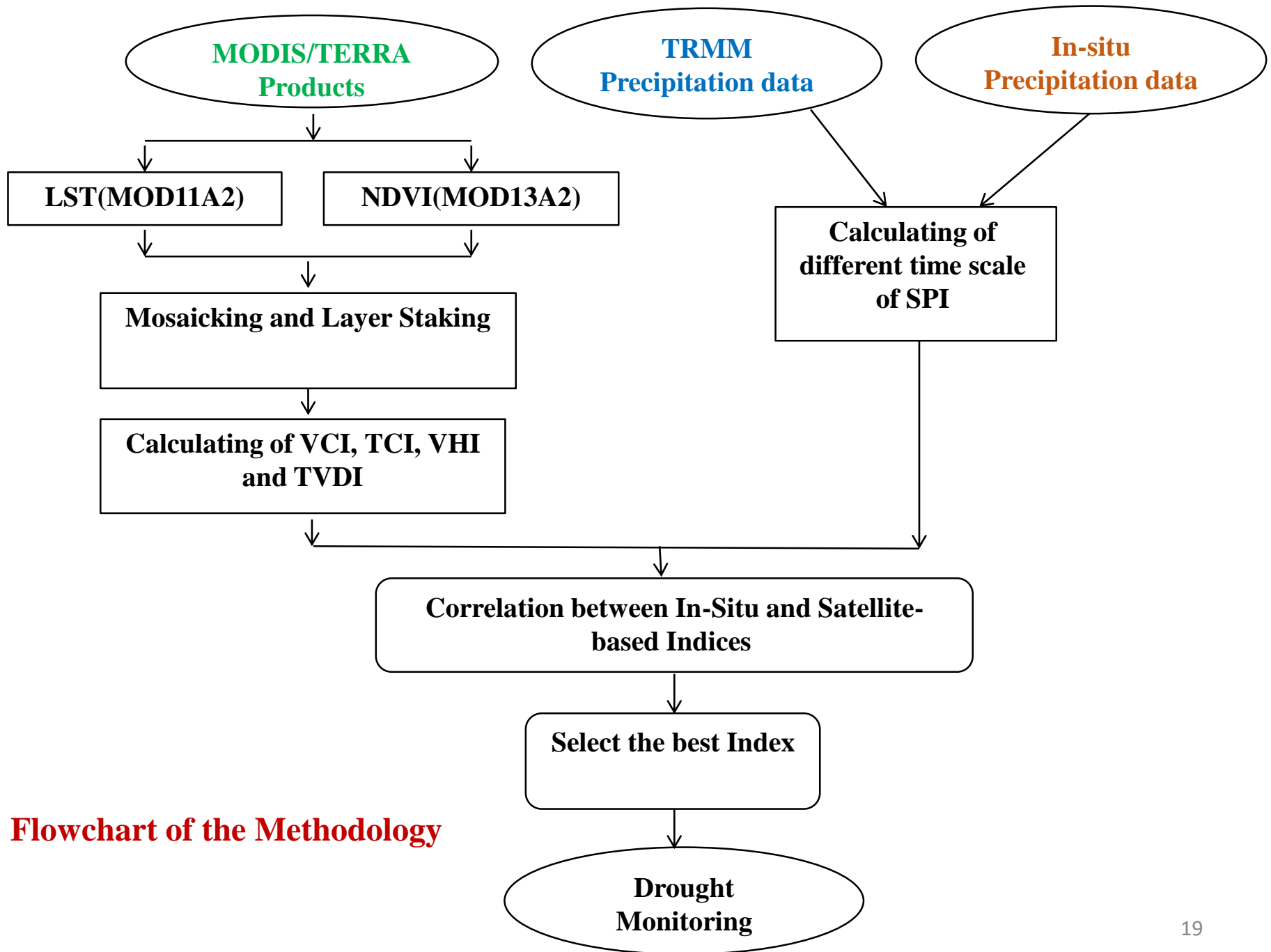
TVDI integrates vegetation indices and surface temperature to monitor soil moisture, so it has a wider range of applicability

$$TVDI = \frac{LST - LST_{min}}{LST_{max} - LST_{min}}$$



The TVDI values range from 0 to 1, which TVDI=0 indicating no evaporation from the soil or limited moisture supply.

TVDI= 1 indicating the maximum evaporation from the soil or unlimited moisture supply.





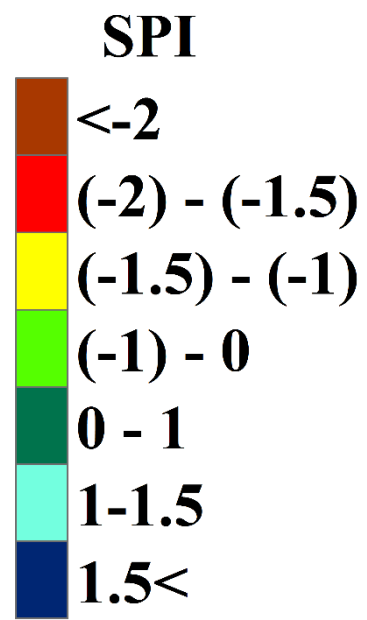
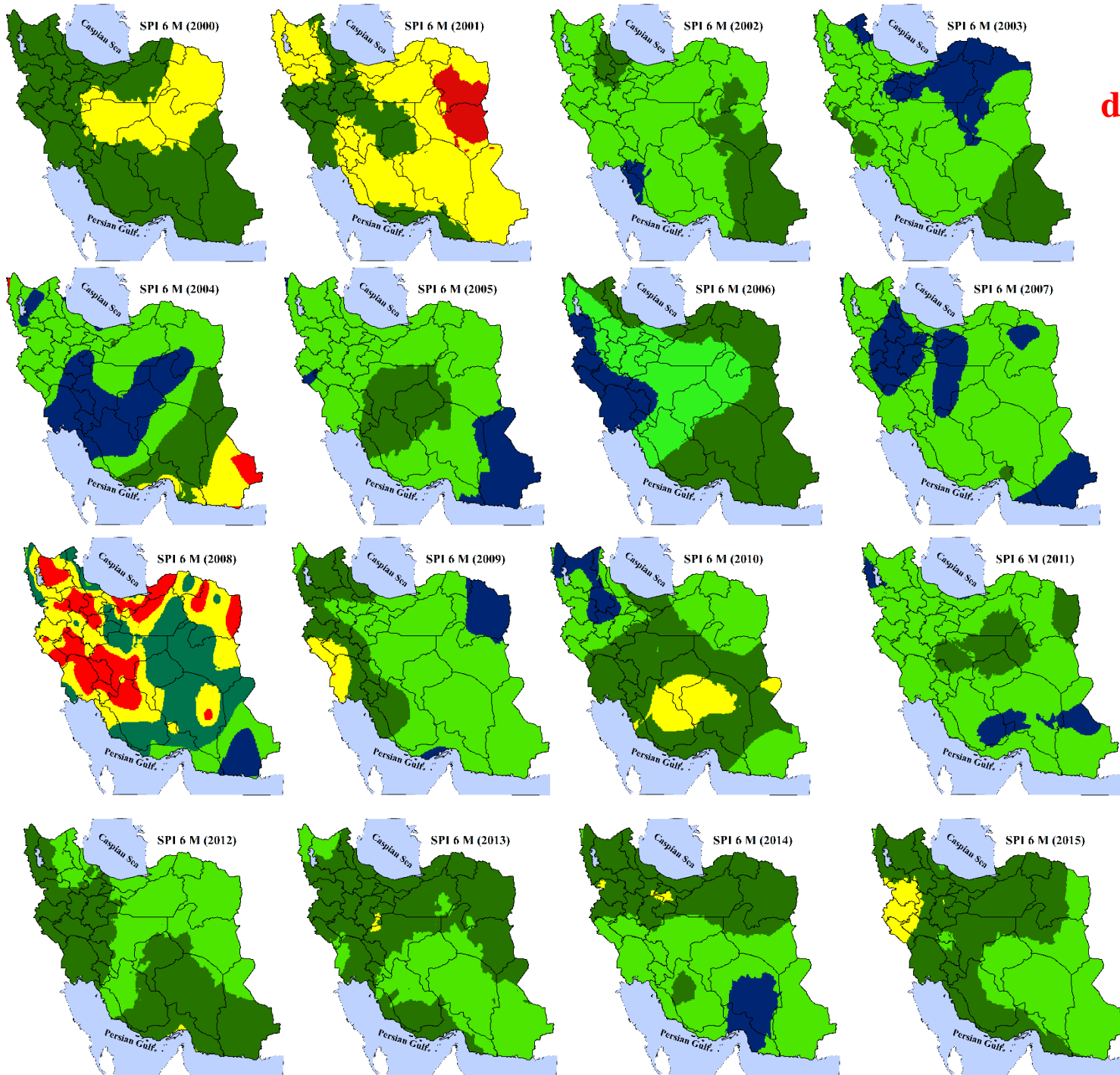
UNITED NATIONS
Office for Outer Space Affairs



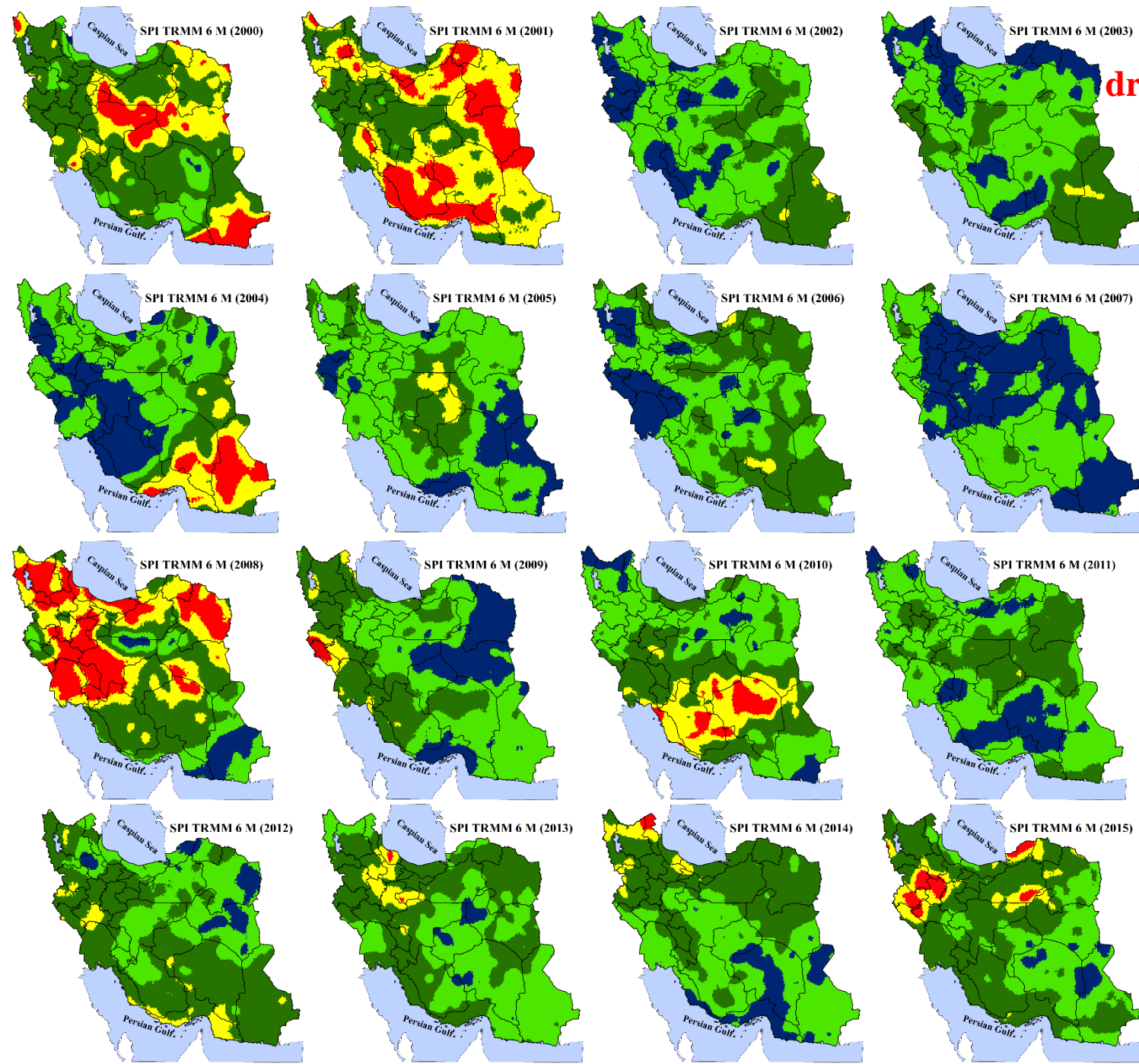
Ministry of I.C.T
IRANIAN SPACE AGENCY

Results and Discussion

**Meteorological
drought maps derived
from station-based
precipitation data**



Meteorological drought maps derived from TRMM precipitation data



SPI

<-2

(-2) - (-1.5)

(-1.5) - (-1)

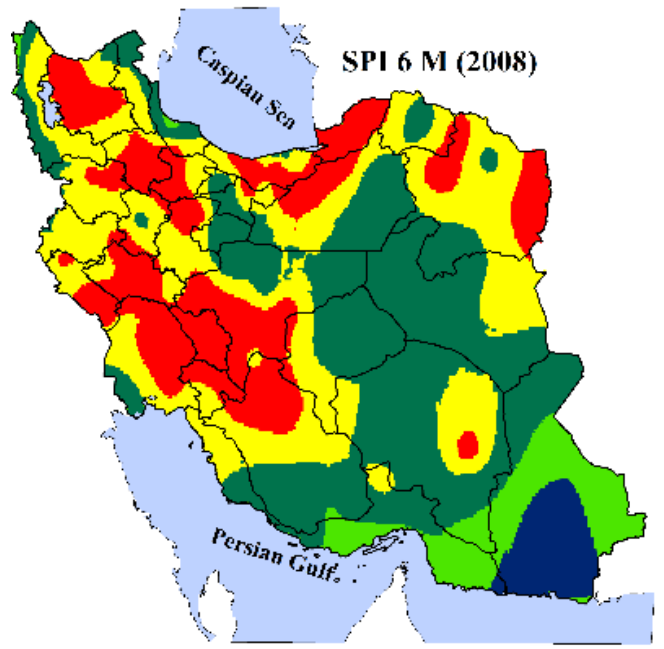
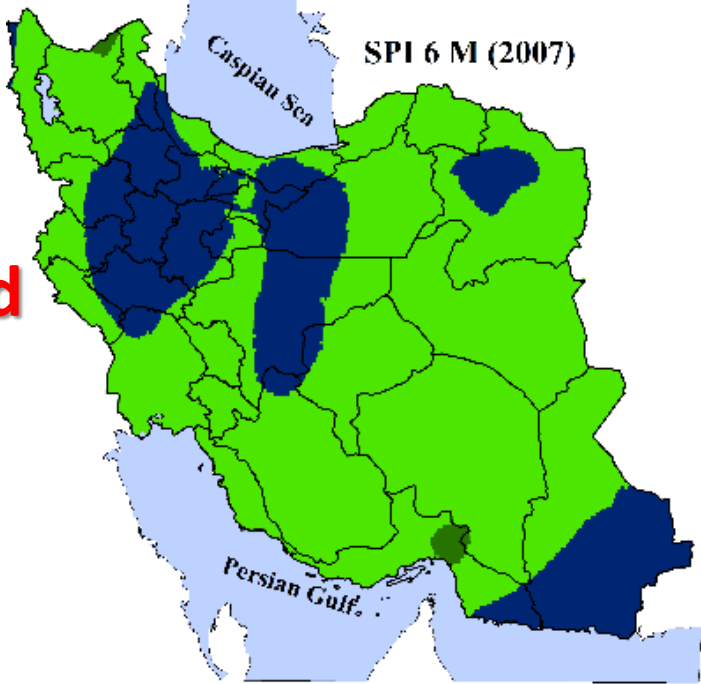
(-1) - 0

0 - 1

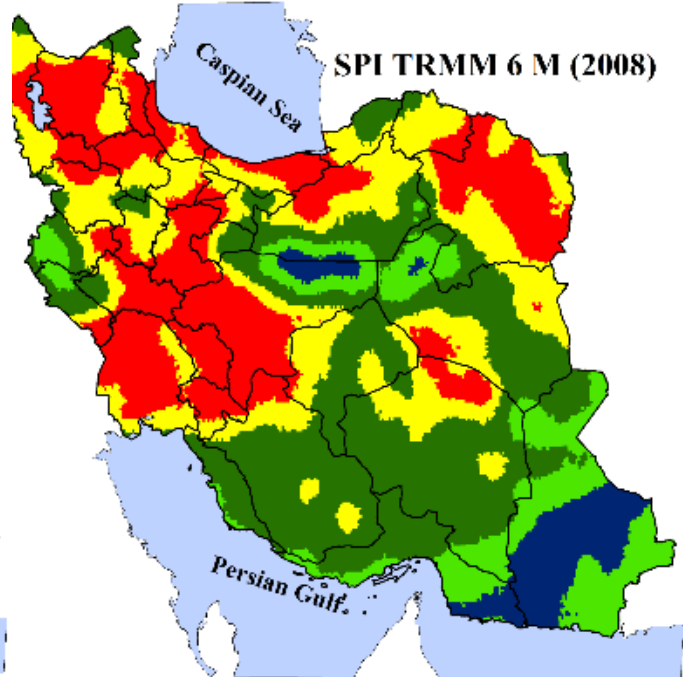
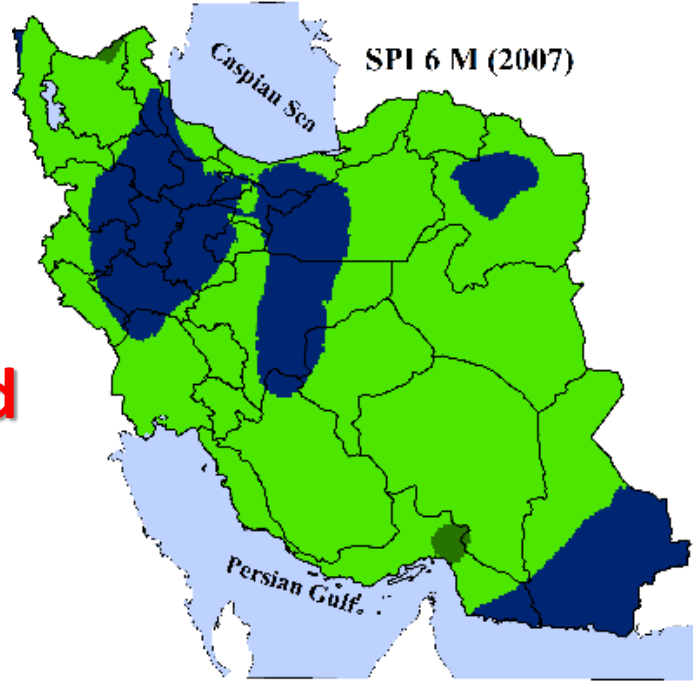
1-1.5

1.5<

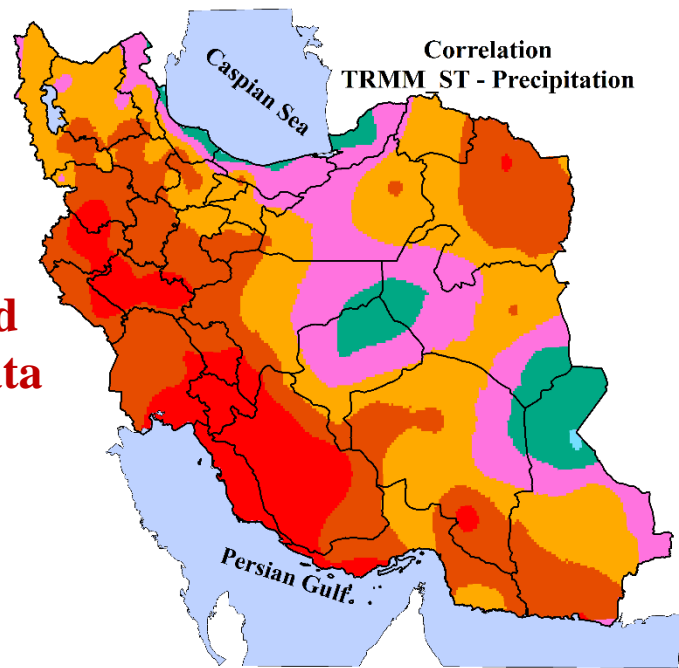
**Ground-based
SPI**



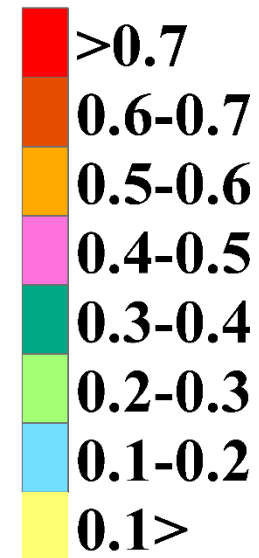
**Satellite-based
SPI**



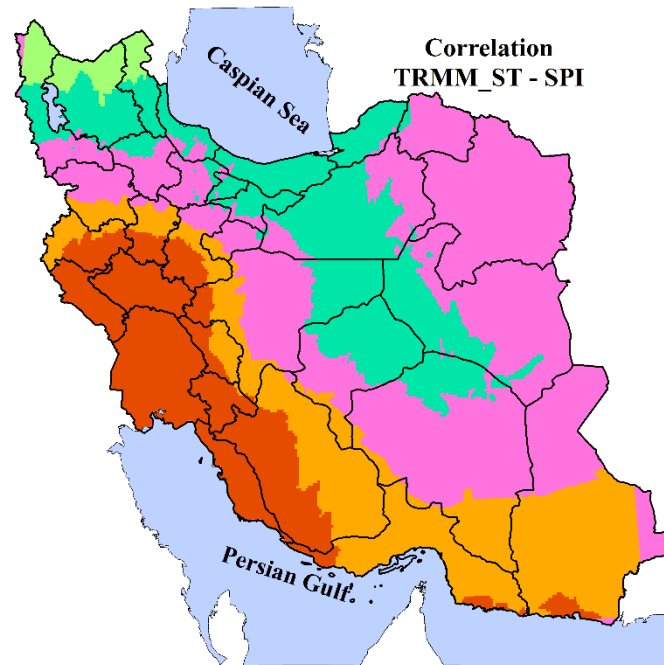
Correlation of station-based precipitation and TRMM data



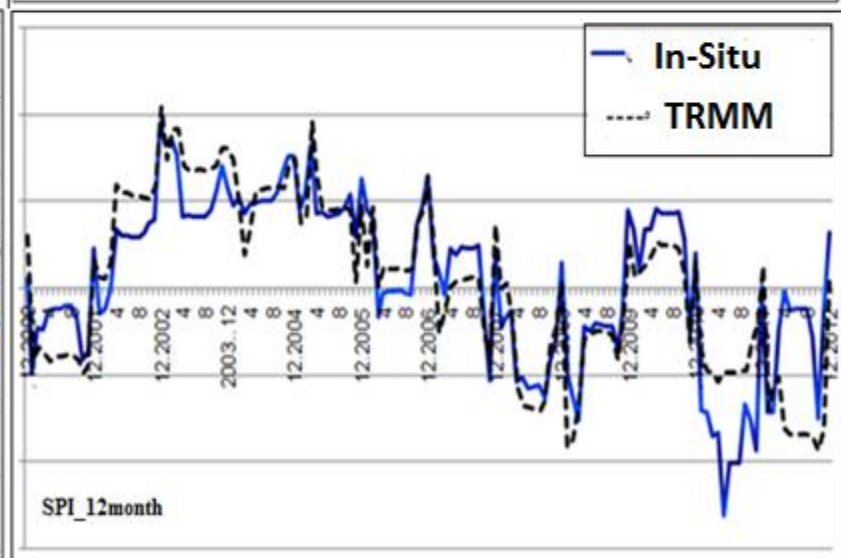
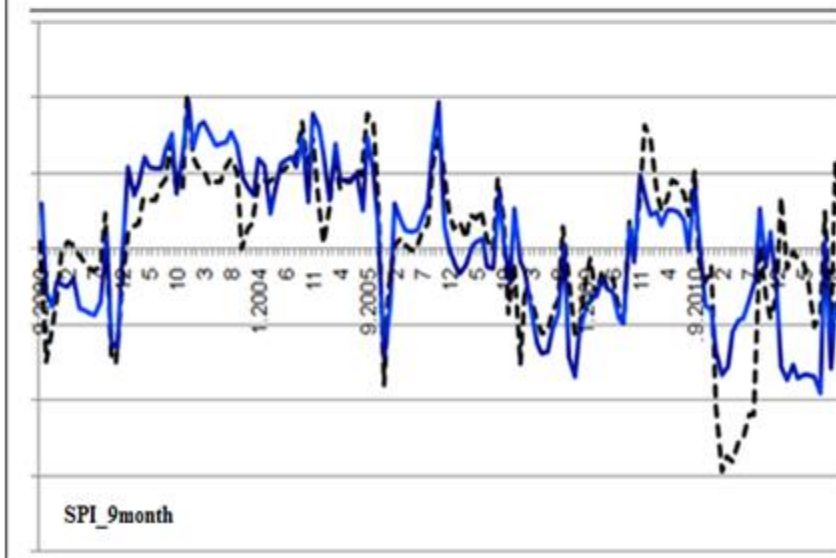
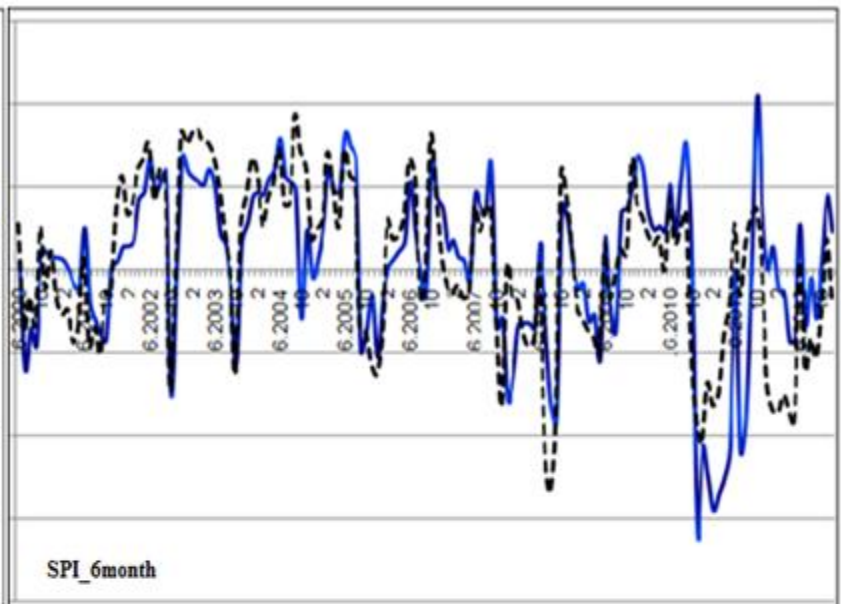
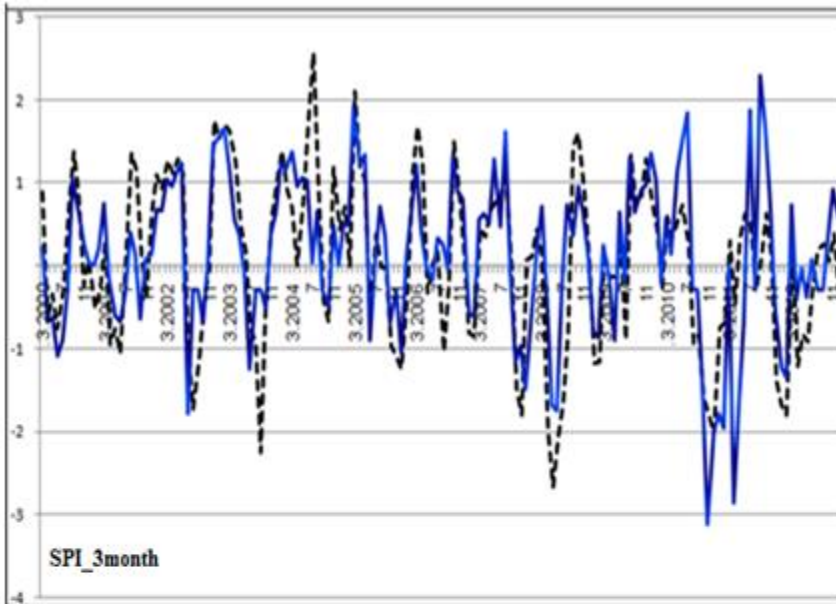
Correlation Coefficient



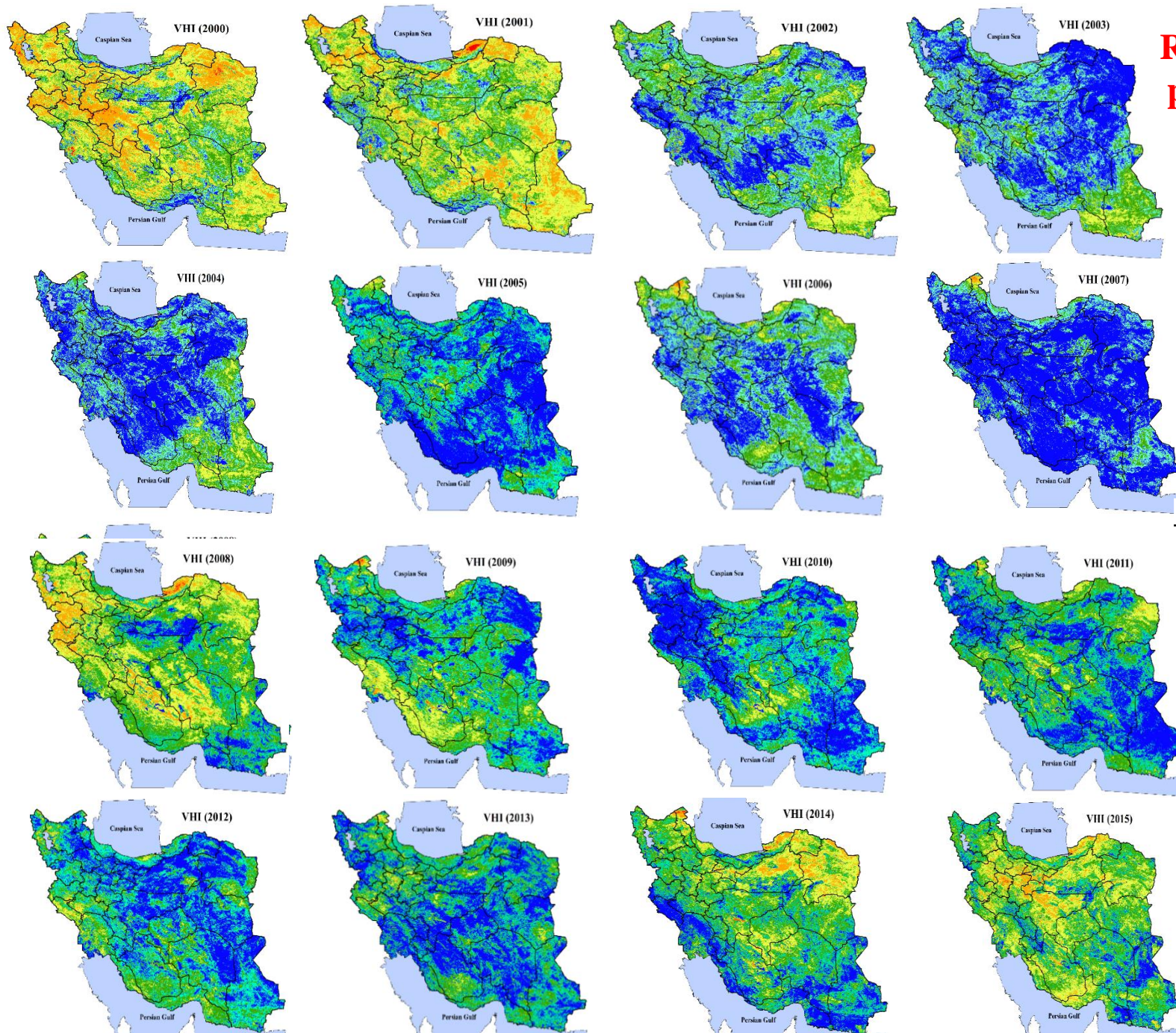
Correlation of station-based SPI and TRMM- SPI



Time Series of the average of In-situ and TRMM SPIs

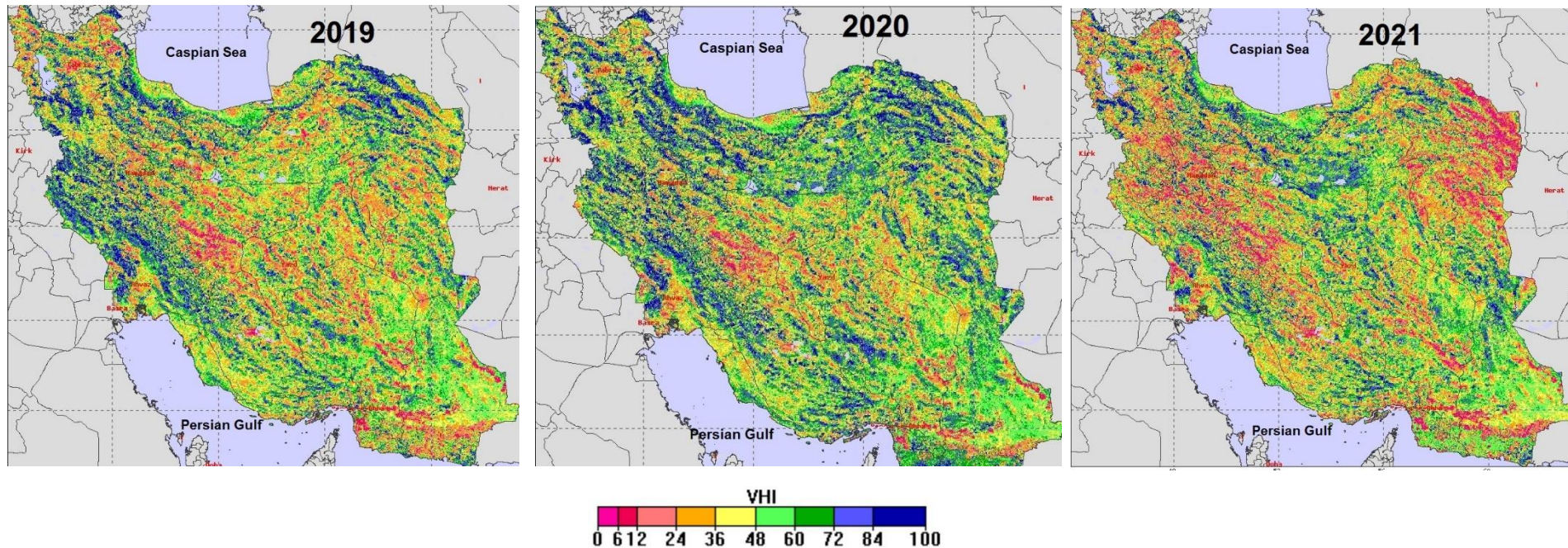


Regional drought patterns derived from VHI

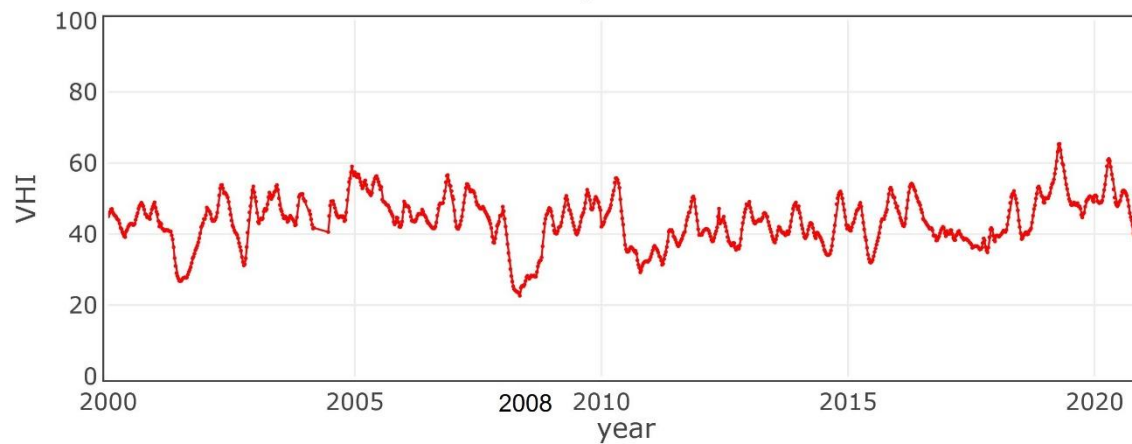
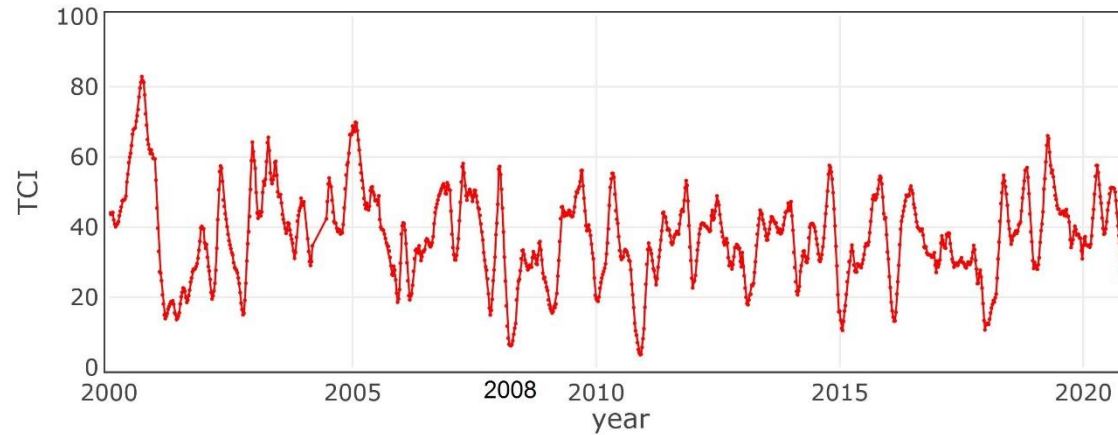
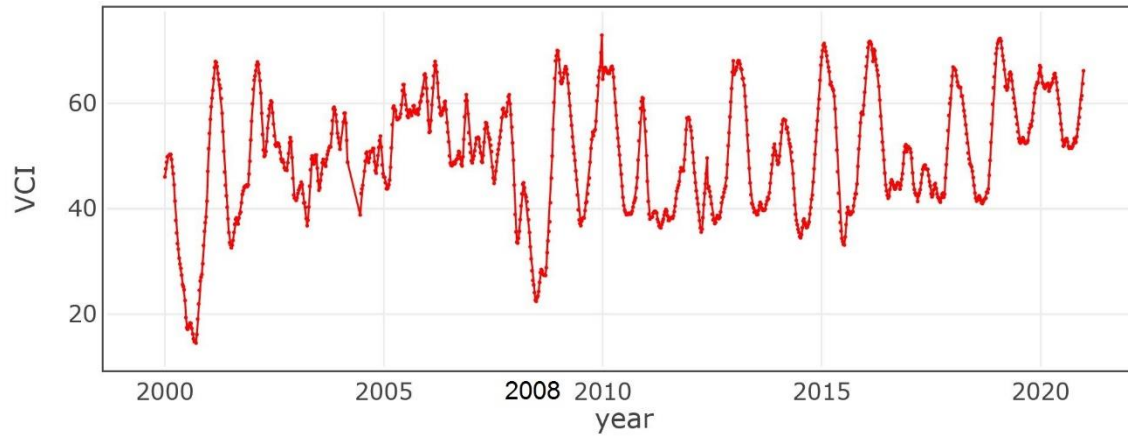


Drought Classes	VHI
Extreme Drought	<10
Severe Drought	10-20
Moderate Drought	20 - 30
Pre Drought	30 - 40
Near Normal	40 - 50
No Drought	50<

Vegetation Health Index (VHI) of last week (5 August) and one and two years ago

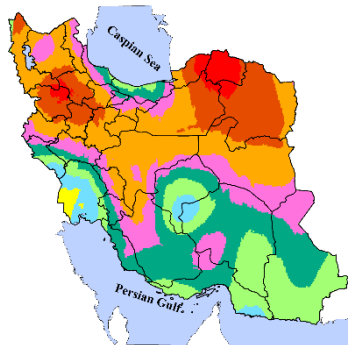
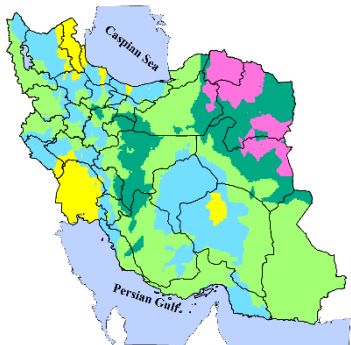
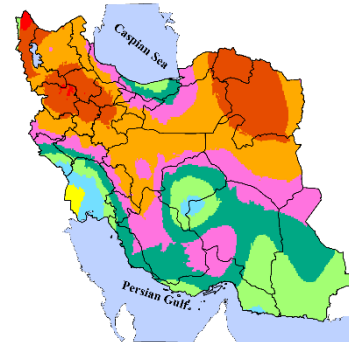
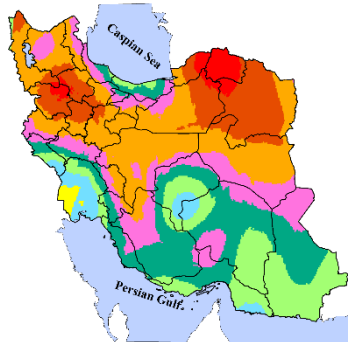
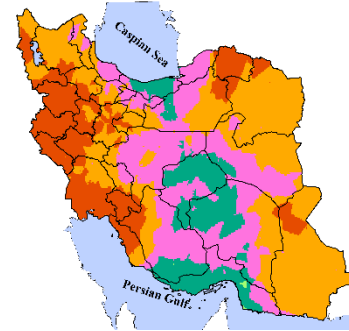
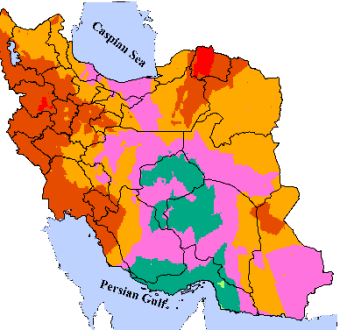
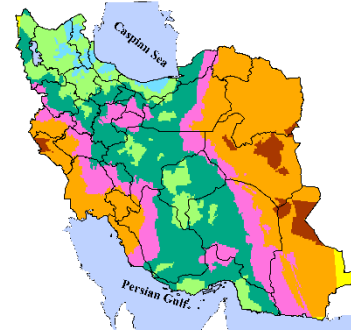
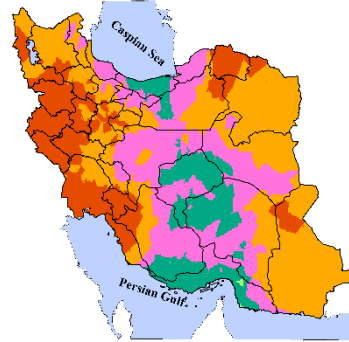
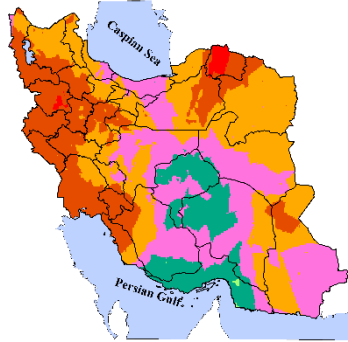
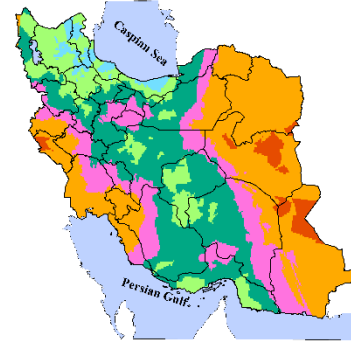
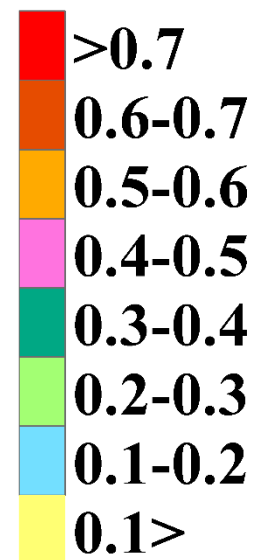


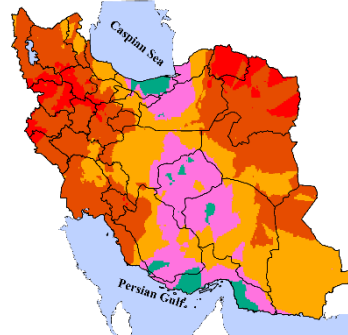
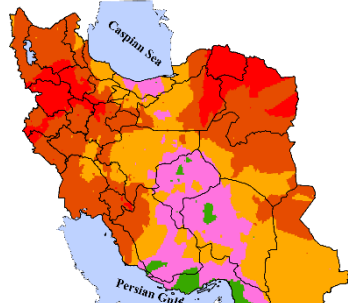
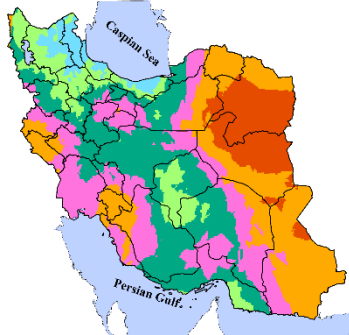
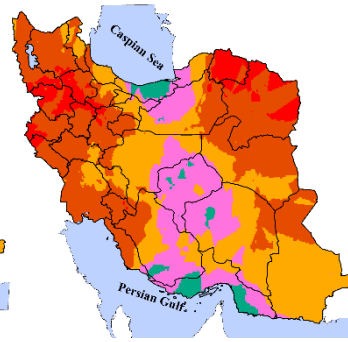
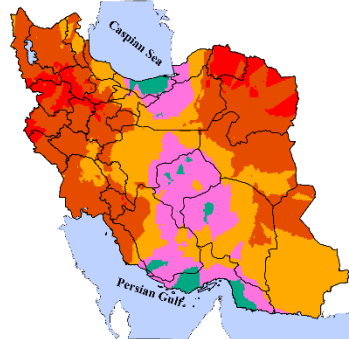
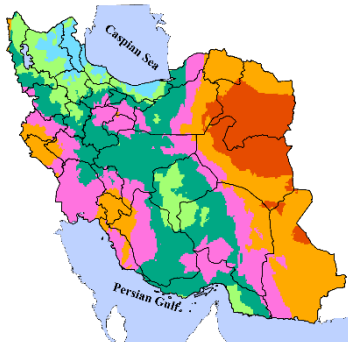
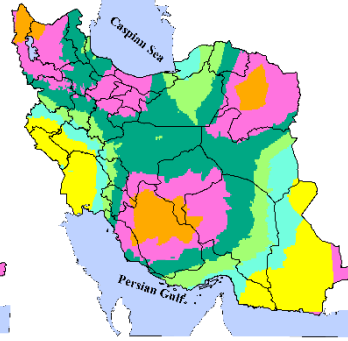
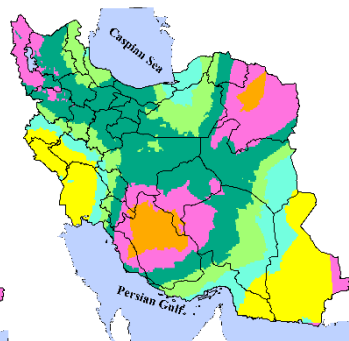
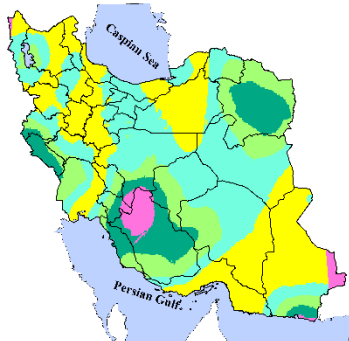
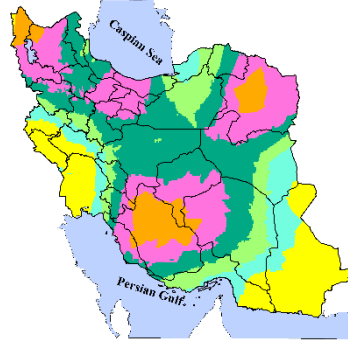
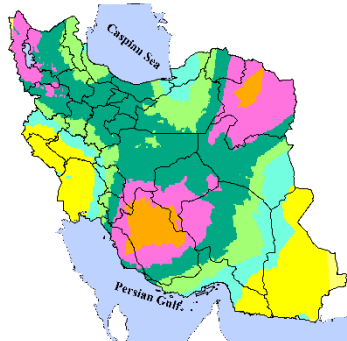
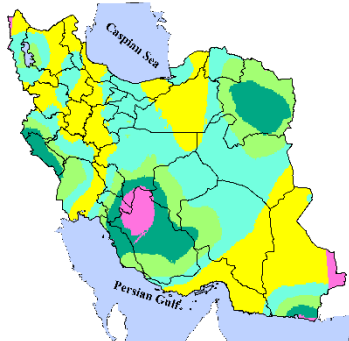
Weekly Average Time Series of VCI, TCI and VHI



SPI-3**SPI-6****SPI-9**

**Coefficient of determination
between remote sensing-
based drought indices and
in situ station-based
drought indices.**

TCI-3**TCI-6****VCI-3****VCI-6****Correlation Coefficient**

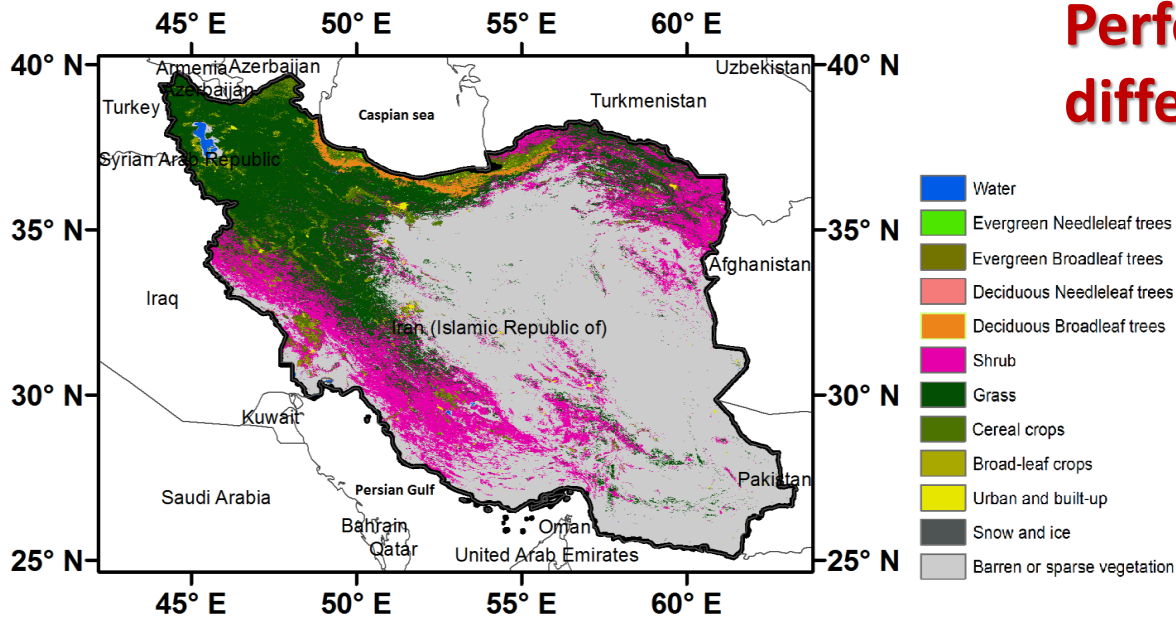
SPI-3**SPI-6****SPI-9****VHI-3****VHI-6****TDVI-3****TDVI-6**

**Coefficient of determination
between remote sensing-
based drought indices and
in situ station-based
drought indices.**

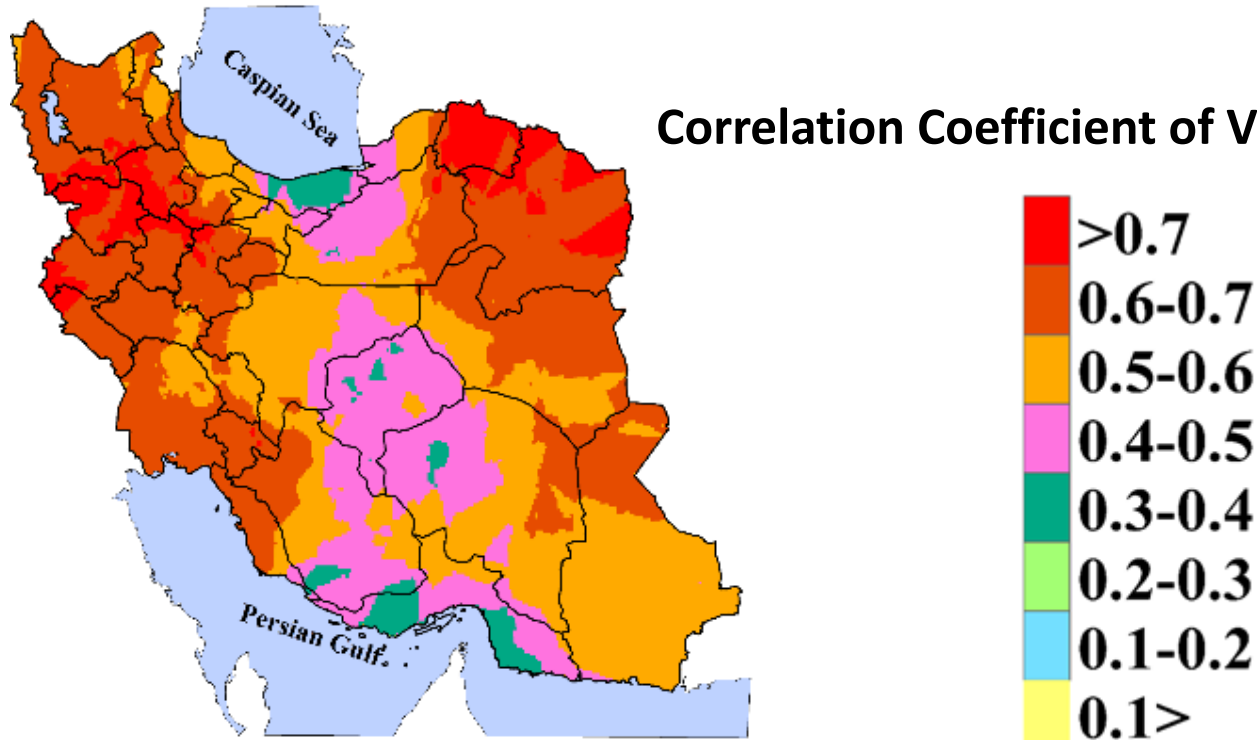
Correlation Coefficient



Performance of VHI in different Land Cover

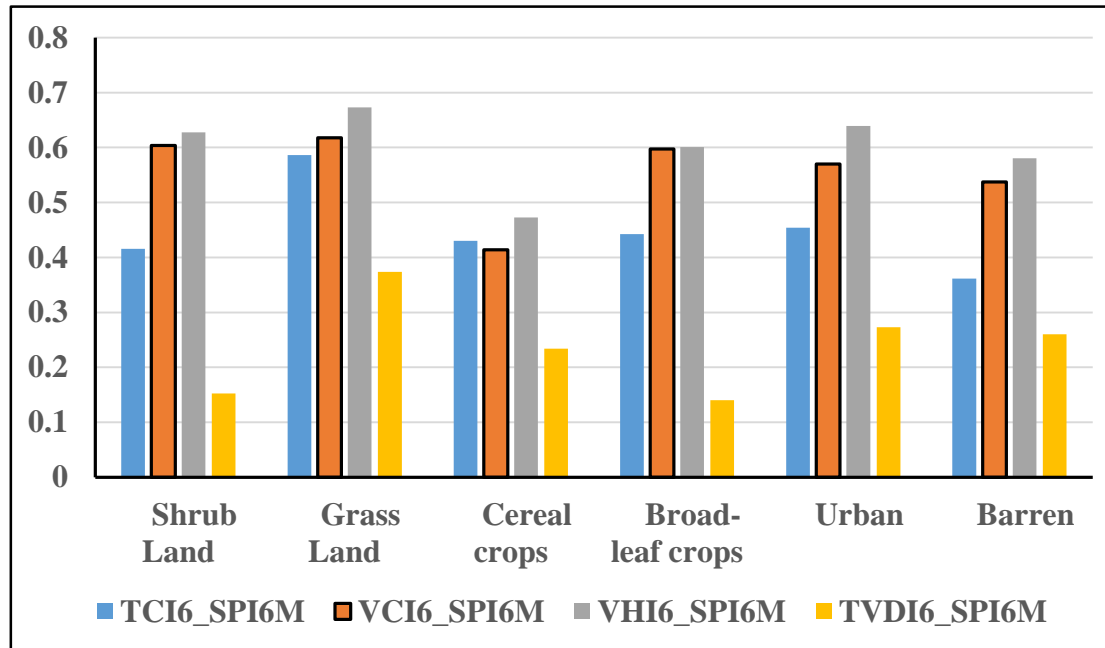


Correlation Coefficient of VHI6 and SPI6



The average of coefficient of determination between agricultural and meteorological drought indices over Iran

	SPI-3M	SPI-6M	SPI-9M
VCI-3M	0.46	0.55	0.53
VCI-6M	0.46	0.55	0.53
TCI-3M	0.57	0.46	0.46
TCI-6M	0.57	0.46	0.46
VHI-3M	0.55	0.60	0.58
VHI-6M	0.55	0.60	0.58
TVDI-3M	-0.40	-0.27	-0.30
TVDI-6M	-0.40	-0.27	-0.30



Coefficient of determination between SPI6M and different agricultural drought indices in different Land Covers



Conclusion

- The correlation between In-situ and TRMM precipitation data is high at the monthly and annual scale, it is followed by SPI. Therefore TRMM data can be used for drought monitoring.
- Regarding the relationship between meteorological and agricultural drought, the highest correlation was found between the six-month meteorological drought (January till Jun) and the six-month agriculture drought (April- September). Therefore there is 3 month lag time between meteorological and agricultural drought in Iran.



Conclusion

- Among the remote sensing based indices the VHI performed best for agricultural drought monitoring.
- In terms of spatial distribution of drought, there is a significant difference between the indicators. Therefore it is necessary to select the appropriate drought index for each specific region, depending on the land cover, climate and other criteria.



Suggestions for future works

- It is suggested to use and evaluate the other drought indices related to Evapotranspiration, Soil Moisture, Groundwater level, Crop Biomass, Snow Cover which can be calculated using various satellite imagery.
- Evaluate the performance of combined remote sensing indices that can be calculated from the combination of various satellite data such as precipitation from TRMM, vegetation and temperature from MODIS for drought monitoring.
- It is recommended to develop a remote sensing web-based system for online drought monitoring in Iran.



Operational Web-based systems for Drought Monitoring



<https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/index.php>



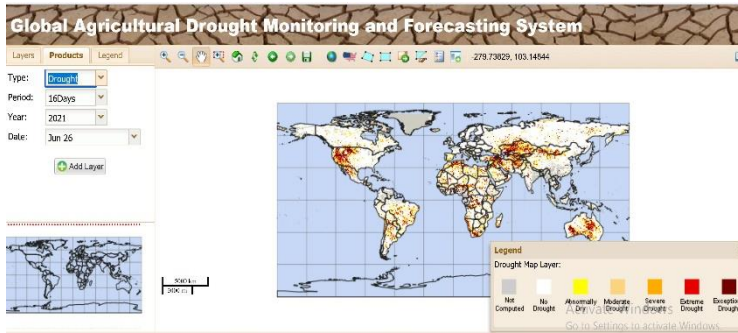
<http://drought.eng.uci.edu/>



<https://earlywarning.usgs.gov/fews>



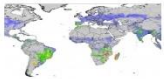
<https://cropmonitor.org/>



<http://gis.csiss.gmu.edu/GADMFS/>



Data Application of the Month: Drought Monitoring



What is drought monitoring used for?

Droughts develop gradually; they are referred to as slow-onset natural hazards. Droughts often do not get any global attention until they trigger a famine or cause wildfires. Unfortunately, response to droughts is too often reactive in terms of crisis management. According to the World Meteorological Organization (WMO), droughts are by far the most damaging of all natural disasters because of their long-term socio-economic impacts. Early detection of droughts is important for managing emerging crop losses to prevent or mitigate possible related famines, and for dealing with increased fire risk.

Satellite imagery helps to monitor precipitation, soil moisture, and vegetation health to support drought early warning systems. It is used to feed monthly drought bulletins and to issue warnings.

How are droughts monitored from Space?

Meteorological droughts are defined by rainfall deficiency over an extended period of time. Meteorological droughts can turn into agricultural droughts, which are characterized by a soil water deficiency and subsequent plant water stress and reduced yield. Agricultural droughts can then turn into hydrological droughts, which refer to deficiencies in surface and subsurface water supplies. The different drought definitions

<https://www.un-spider.org/links-and-resources/data-sources/daotm-drought>





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IRANIAN SPACE AGENCY

United Nations/Islamic Republic of Iran Workshop on the

Space Technology Applications
for **Drought, Flood** and **Water**
Resources Management

9-11 August 2021, Tehran, Iran



**Thanks for
Your Attention**

