

**Course Name: Watershed Hydrology**

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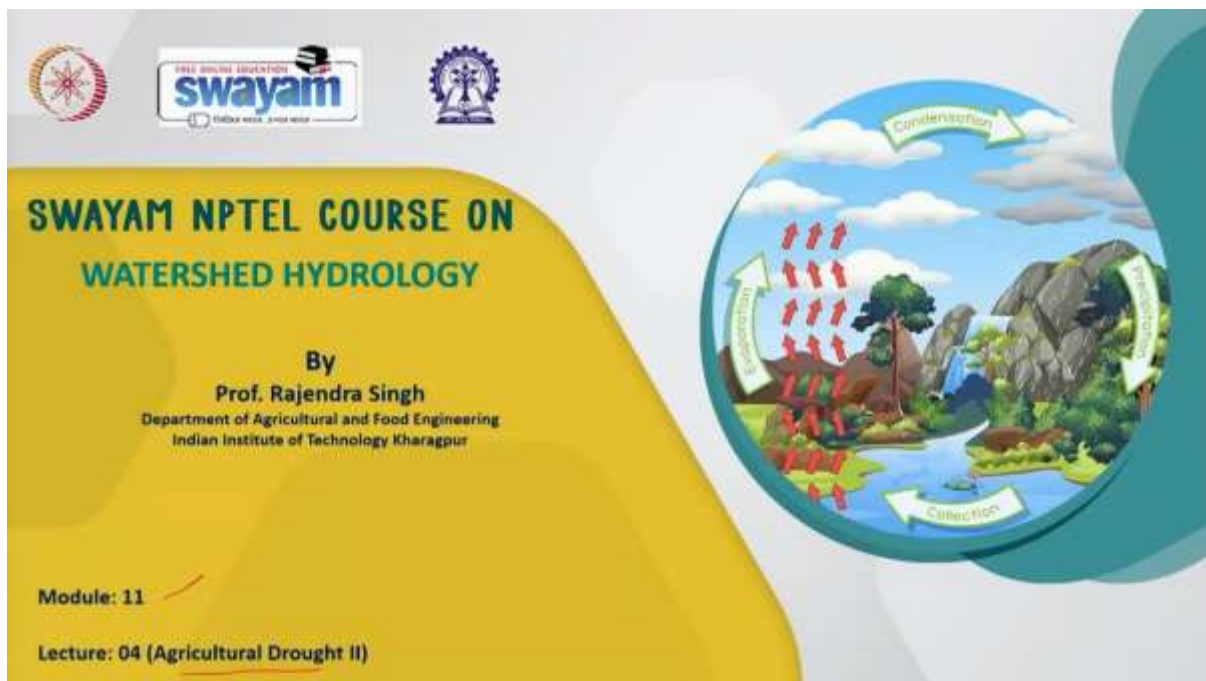
**Department Name: Agricultural and Food Engineering**

**Institute Name: Indian Institute of Technology Kharagpur**

**Week: 11**

**Lecture 54: Agricultural Drought II**

Hello friends, welcome back to this online certification course on watershed hydrology. I am Rajendra Singh, Professor in the Department of Agriculture and Food Engineering at the Indian Institute of Technology Kharagpur. We are in module 11, and this is lecture number 4 where we will be discussing part 2 of agricultural drought.



In this lecture, we will focus on remote sensing-based agricultural drought indices.

## Content- Agricultural Drought II

- Remote-Sensing Based Agricultural Drought Indices

We discussed agricultural drought indices in the previous lecture, but they were not remote sensing-based; mostly, they were based on ETA and ET0. Today, we will delve into remote sensing-based agricultural drought indices, meaning the parameters or variables can be obtained directly from satellite data. These indices include NDVI (Normalized Difference Vegetation Index), Transform Vegetation Index DVI, Enhanced Vegetation Index (EVI), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), Difference Vegetation Index (DVI), Soil Adjusted Vegetation Index (SAVI), Visible Atmospheric Vegetation Index (VARI), and Green Vegetation Index (GVI). In fact, there are many more, but I will provide definitions and details for these indices.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

- Normalized Difference Vegetation Index (NDVI)
- Transformed vegetation index (TVI)
- Enhanced vegetation index (EVI)
- Vegetation condition index (VCI)
- Temperature condition index (TCI)
- Difference Vegetation Index (DVI)
- Soil Adjusted Vegetation Index (SAVI)
- Visible Atmospheric Resistant Index (VARI)
- Green Vegetation Index (GVI)

Let's begin with NDVI, which is a numerical indicator utilizing the visible and near-infrared bands of the electromagnetic spectrum, derived from satellite data. It is adapted to analyse remote sensing measurements and assess the greenness in the vegetation cover. So, basically, it gives you an idea about the level of greenness in the vegetation. It is useful for timely estimation of vegetation conditions. Based on the greenness or NDVI value, we can determine whether the plant is healthy or not. The advantages are that it is used for monitoring vegetation growth and health, serving as a good indicator of vegetation growth and health.

However, a disadvantage is that cloud cover can create a problem. Obviously, if there is cloud cover, you will not be able to obtain the data, thus unable to estimate NDVI. In fact, this is the drawback for almost all remote sensing agricultural drought indices.

**Drought Indices**

**Remote-sensing-based Agricultural Drought Indices**

- ❑ **Normalized Difference Vegetation Index (NDVI)**
- ✓ It is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum
- ✓ It is adopted to analyse remote sensing measurements and assess the greenness in the vegetation cover
- ✓ NDVI is useful for the timely estimation of vegetation condition

➤ **Advantage:**

- ✓ NDVI is used for monitoring vegetation growth and health

➤ **Disadvantage:**

- ✓ Cloud cover can create a problem

Basically, it is given by this relationship:  $NDVI = \frac{NIR - R}{NIR + R}$ , where NIR is the reflectance in the near-infrared band and R is the reflectance in the red band of the satellite. So, depending on the type of satellite you are using, different satellites have different cameras and bands. Therefore, based on the satellite, you need to utilize either the NIR or red band to acquire the data. NDVI ranges from minus 1 to 1, and there is variation in NDVI for different crop growth periods. As you can see, this variation reflects the greenness. So, obviously, it starts with a low value and as the greenness increases, it also increases. But as the crop matures, meaning the greenness decreases, NDVI values also decrease. Based on NDVI, the classes of drought are defined. If its value is less than or equal to minus 0.2, then it is severe drought. If it falls between minus 0.2 and minus 0.05, then it is moderate drought. If it falls between minus 0.05 and 0.1, then it is near normal, and if it is greater than 1, then it is above optimum. So, if the NDVI value is greater than 1, then it indicates the vegetation is perfectly fine. Otherwise, there is a drought condition if the values are negative. Based on the NDVI value, you can estimate whether the crop growth is satisfactory or not.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

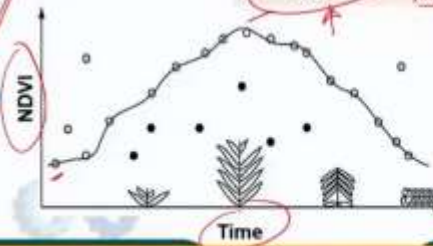
#### Normalized Difference Vegetation Index (NDVI):

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

Where NIR = Reflectance in near infra-red (NIR) band

R = Reflectance in red (R) band of satellite

- ✓ NDVI ranges from -1 to 1
- ✓ There is a variation in NDVI for different crop growth periods



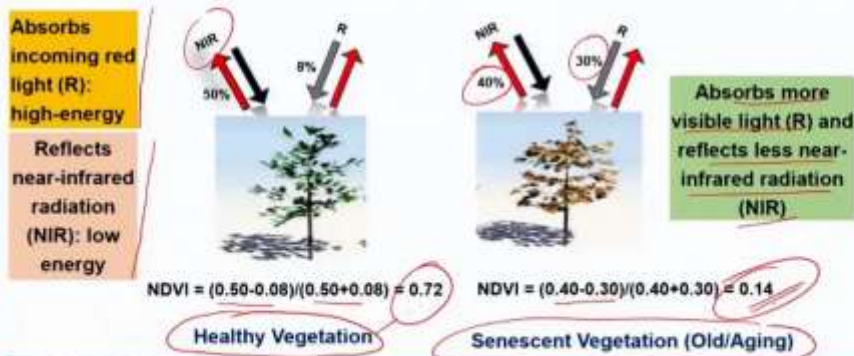
NDVI	Class for drought
$\leq -0.2$	Severe drought
$> 0.2$ and $\leq -0.05$	Moderate drought
$> -0.05$ and $\leq 0.1$	Near normal
$> 0.1$	Above optimum

If you examine the NDVI typically for healthy vegetation compared to senescent or aging vegetation, you'll find that healthy vegetation absorbs incoming red light, which is high energy, and reflects near-infrared radiation, which is low energy. Typically, if the values are, let's say, 50 percent of NIR reflected and 0.08 of incoming light absorbed, based on this value, the NDVI comes out to be 0.72. Remember, anything above 0.1 is considered healthy according to this classification. Now, if you look at old or aging plantations, they absorb more visible light, possibly even 30 percent, and reflect less near-infrared light, maybe only 40 percent. So, the difference between these two is less, resulting in an NDVI value of 0.14. Obviously, one will indicate a green plant, while the other will show an older, aging plant. Thus, the impact of greenness can be reflected by NDVI values, allowing us to make judgments about the health of vegetation for a given location.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

□ Normalized Difference Vegetation Index (NDVI):



Now, let's take an example of NDVI calculation. Calculate the following NDVI ratios and comment on drought conditions: in case 1, where the reflectance of red light is 0.08 and reflected near-infrared light is 0.55, and in case 2, where the reflectance of red light is 0.4 and reflected near-infrared light is 0.45. Of course, we know that in NIR, these are the two values we focus on in calculating NDVI. In case 1, with R as 0.08 and NIR as 0.55, the NDVI comes out to be 0.74. This means it is above optimal, indicating healthy vegetation with no drought condition as NDVI is above 0.1.

## Drought Indices

### Normalized Difference Vegetation Index (NDVI)

#### Example 1

Calculate the following NDVI ratios and comment on drought{

- Reflectance of red-light 0.08, Reflected near-infrared light 0.55
- Reflectance of red-light 0.4, Reflected near-infrared light 0.45

**Solution:**

- Reflectance in the red (R) band of the satellite = 0.08
- Reflectance in near infra-red (NIR) band = 0.55
- Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{(NIR - R)}{(NIR + R)} = \frac{(0.55 - 0.08)}{(0.55 + 0.08)} = 0.74$$

- The vegetation is healthy and there is no drought condition as NDVI is above 0.1

NDVI	Class for drought
$\leq - 0.2$	Severe drought
$> 0.2$ and $\leq - 0.05$	Moderate drought
$> - 0.05$ and $\leq 0.1$	Near normal
$> 0.1$	Above optimum

In case 2, with R as 0.4 and NIR as 0.45, the value we get is 0.06. Here, it falls between -0.05 and 0.1, indicating a near-normal condition. So, the drought condition is near normal. Although there is no drought per se, it is almost tending towards drought, being just below optimal or

slightly below optimal condition, you could say. Based on R and NIR values, we can determine the NDVI value for different vegetation and make our judgments accordingly.

## Drought Indices

### Normalized Difference Vegetation Index (NDVI)


**Solution:**

- Reflectance in the red (R) band of the satellite = 0.4
- Reflectance in near infra-red (NIR) band = 0.45
- Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{(NIR - R)}{(NIR + R)} = \frac{(0.45 - 0.4)}{(0.45 + 0.4)} = 0.06$$

- The drought condition is near normal as NDVI is between - 0.05 to 0.1

NDVI	Class for drought
$\leq - 0.2$	Severe drought
$> 0.2$ and $\leq - 0.05$	Moderate drought
$> - 0.05$ and $\leq 0.1$	Near normal
$> 0.1$	Above optimum




Next, let's discuss TVI, which stands for Transform Vegetation Index. It is a modification of the NDVI, which is a widely used measure of vegetation greenness and is particularly useful in assessing vegetation conditions under water stress or drought conditions in agricultural areas. So, obviously, if you notice water stress or drought conditions in an agricultural area, TVI will likely be more useful. The index is sensitive to changes in both leaf area and chlorophyll content, making it a valuable tool for monitoring the health and stress of crops. Therefore, it is considered a better indicator than NDVI, hence the term "modified NDVI".

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

**Transformed Vegetation Index (TVI):**

- It is a modification of the normalized difference vegetation index (NDVI), which is a widely used measure of vegetation greenness
- It is particularly useful in assessing vegetation conditions under water stress or drought conditions in agricultural areas
- The index is sensitive to changes in both leaf area and chlorophyll content, making it a valuable tool for monitoring the health and stress of crops



In this case, the formula used is similar to NDVI, with the addition of 0.5 and the use of the square root. Essentially, in terms of NDVI, TVI can be understood as the square root of NDI plus 0.5. R and NIR remain the same, but here it is defined in terms of Landsat Thematic Mapper Satellite Bands. Band 3 of the Landsat TM Satellite, which represents the red band, is denoted as R, while Band 4, in the near-infrared spectrum, represents NIR. So, basically, if you are using Landsat TM satellite data, which is very popular, freely available, and widely used, you need to utilize bands 3 and 4 for R and NIR, respectively, to calculate TVI. In fact, these values can also be used for estimating NDVI. Typically, TVI ranges between 0 and 1.2, indicating TVI versus drought severity. As TVI values decrease, drought severity increases. Based on TVI value, drought classes are defined as follows: if it is within the normal range, then there is no drought; if it falls within threshold 1, then it is a mild drought; within threshold 2, it's a moderate drought; within threshold 3, it's a severe drought; and below threshold 3, it's an extreme drought. So, this is how one can estimate the drought condition based on TVI values.

**Drought Indices**

**Remote-sensing-based Agricultural Drought Indices**

□ **Transformed Vegetation Index (TVI):**

$$TVI = \left[ \left( \frac{NIR - R}{NIR + R} \right) + 0.5 \right]^{0.5}$$

$$TVI = \sqrt{NDVI + 0.5}$$

Where R = reflectance of Landsat TM (Thematic Mapper) satellite band 3 (visual spectrum - Red band)

NIR = reflectance of Landsat TM satellite band 4 (near-infra red spectrum)

✓ TVI ranges between 0 and 1.2

TVI	Class for drought
> Normal Range	No drought
within Threshold 1	Mild drought
within Threshold 2	Moderate drought
within Threshold 3	Severe drought
below Threshold 3	Extreme drought

TVI

Drought severity

Regarding its advantages, TVI is designed to be less sensitive to atmospheric conditions compared to other vegetative indices like NDVI. Atmospheric correction is taken into account while estimating TVI. Additionally, it can be used in combination with other vegetation indices to provide complementary information about vegetation dynamics. One disadvantage is that it may not be sensitive to early stages of stress in vegetation. In some cases, by the time TVI values indicate stress, significant damage may already have occurred. So, this is a point of caution. The angle of the sun and the presence of shadows can impact the reflectance values used in TVI calculations, which is typical for any satellite-based data. However, one significant drawback of TVI is that it gives a late indication of drought onset.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Transformed Vegetation Index (TVI):

##### ▪ Advantages:

- ✓ TVI is designed to be less sensitive to atmospheric conditions compared to other vegetation indices like NDVI
- ✓ TVI can be used in combination with other vegetation indices to provide complementary information about vegetation dynamics

##### ▪ Disadvantages:

- ✓ TVI may not be as sensitive to early stages of stress in vegetation. In some cases, by the time TVI values indicate stress, significant damage may have already occurred
- ✓ The angle of the sun and the presence of shadows can impact the reflectance values used in TVI calculations

Moving on to the third index, the Enhanced Vegetation Index (EVI), it aims to reduce atmospheric impacts and decouple the canopy background signal, making it an optimized indicator of vegetation. The purpose is to improve vegetation monitoring and create a stronger, more sensitive vegetation signal, especially in areas with high vegetation density. So, basically, they all function on the same principle, with some modifications. Essentially, the canopy background signal is decoupled when calculating EVI. It is widely used in precision agriculture, where precise information about crop conditions is crucial. By removing background information, EVI provides a more precise picture, which is why it is preferred in precision agriculture where accurate information is necessary for effective management. Farmers can use EVI data to identify areas of fields that may be experiencing drought stress, nutrient deficiencies, or other issues that require targeted management. In fact, because it is precise, within or among fields, it can provide insight into drought stress, allowing for precise management procedures to be adopted to address the issue.



## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### Enhanced Vegetation Index (EVI):

- ✓ By reducing atmospheric impacts and decoupling the canopy background signal, the enhanced vegetation index is an optimised indicator of vegetation that is intended to improve vegetation monitoring and create a stronger, more sensitive vegetation signal in areas with high biomass
- ✓ EVI is widely used in precision agriculture, where precise information about crop conditions is crucial
- ✓ Farmers can use EVI data to identify areas of fields that may be experiencing drought stress, nutrient deficiencies, or other issues that require targeted management

EVI is calculated using a relationship specifically designed for MODIS satellite data, which we discussed earlier. MODIS provides free satellite data commonly used by researchers. In the calculation, NIR and R represent the red spectrum and near-infrared spectrum, respectively. Additionally, B represents the reflectance of the near-blue spectrum band, while L accounts for canopy background adjustment. Coefficients C1 and C2, along with G as the gain factor, are utilized in EVI calculation, making it a more precise remote sensing-based agricultural drought index.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### Enhanced Vegetation Index (EVI):

$$EVI = G \times \frac{(NIR - R)}{(NIR + C_1 \times R - C_2 \times B + L)}$$

For use with MODIS satellite data

Where  $R$  = Reflectance of Red spectrum-band

$NIR$  = Reflectance of near-infra red spectrum-band

$B$  = Reflectance of near blue spectrum-band

$C_1$  and  $C_2$  are the coefficients

$G$  = Gain factor

$L$  = Canopy background adjustment factor

NIR, R, and B are atmospherically corrected or partially atmospherically corrected surface reflectances. L represents the canopy background adjustment, which addresses non-linear differential NIR and red radiant transfer through a canopy. This adjustment ensures a more

precise indicator of vegetation health. Coefficients  $C_1$  and  $C_2$  are part of the aerosol resistance term, using the blue band to correct for aerosol influences in the red band. So, of course, the red band data is also corrected for precise estimation of the vegetation index. The coefficients adopted for the MODIS EVI algorithm are as follows:  $L$  is 1,  $C_1$  is 6,  $C_2$  is 7.7, and  $G$  is 2.5. Therefore, when using MODIS data and the equation, these coefficients are already assigned values. Next, if you have values for  $R$ , NIR, and  $B$ , then you can estimate EVI.

**Drought Indices**

**Remote-sensing-based Agricultural Drought Indices**

- ❑ **Enhanced Vegetation Index (EVI):**
  - ✓ NIR/R/B are atmospherically-corrected or partially atmosphere-corrected surface reflectance
  - ✓  $L$  is the canopy background adjustment that addresses non-linear, differential NIR and red radiant transfer through a canopy
  - ✓  $C_1$  and  $C_2$  are the coefficients of the aerosols resistance term, which uses the blue band to correct for aerosol influences in the red band
  - ✓ The coefficients adopted in the MODIS-EVI algorithm are,  $L = 1$ ,  $C_1 = 6$ ,  $C_2 = 7.7$ , and  $G$  (gain factor) = 2.5

Basically, while determining EVI, a baseline or normal range of EVI values during periods of typical or non-drought conditions is established first. This can be based on historical data or observations during seasons without drought stress. So, you can either use historical data where there was no drought condition or ideal conditions were present, or you can use current season data where no drought is observed, and then develop a baseline value. Afterward, you calculate anomalies or deviations by comparing the current EVI values with the established baseline or normal range. This step helps identify deviations from typical conditions, which can be indicative of drought stress. EVI within the standard deviation of the baseline defines the drought class. If it is within plus or minus 1 standard deviation, it is considered normal; below minus 1 indicates mild drought, below minus 2 is moderate drought, and below minus 3 signifies severe drought conditions. Essentially, the standard deviation is used to define the drought class, indicating the deviation of EVI from the normal or baseline.

## Drought Indices

### □ Enhanced Vegetation Index (EVI):

- ✓ Determine a baseline or normal range of EVI values during periods of typical or non-drought conditions
- ✓ This can be based on historical data or observations during seasons without drought stress
- ✓ Calculate anomalies or deviations by comparing the current EVI values with the established baseline or normal range
- ✓ This step helps identify deviations from typical conditions, which can be indicative of drought stress

EVI within standard deviation of base line	Drought class
±1	Normal range
Below -1	Mild drought
Below -2	Moderate drought
Below -3	Severe drought

Next, we move on to the vegetation condition index (BCI), which compares the current NDVI to a range of values observed during the same period in the previous year. So, basically, it is based on NDVI values of current and previous data. The equation used for this is shown here.  $\text{NDVI}_J - \text{NDVI}_{\text{min}}$ , divided by  $\text{NDVI}_J - \text{NDVI}_{\text{max}}$ , and then multiplied by 100 to convert it into a percentage. Here,  $\text{NDVI}_J$  represents the NDVI for a specific year, month, or week,  $\text{NDVI}_{\text{min}}$  is the long-term minimum NDVI for that year, month, or week, and  $\text{NDVI}_{\text{max}}$  is the long-term maximum NDVI for the same period. If you want to calculate the Vegetation Condition Index (VCI) for a particular month or week, then you obviously need long-term data, typically spanning 20 years. This helps determine the minimum and maximum NDVI values for that specific time frame, allowing you to calculate the VCI value for that particular week or month. The drought class is defined based on the percentage value. If it is less than 10 percent, then it indicates extreme drought; 10 to 20 percent suggests severe drought; 20 to 35 percent signifies moderate drought; 35 to 50 percent indicates no drought; and if it is greater than 50 percent, it suggests normal or wet conditions. Essentially, this can be considered an advanced version of NDVI, where not only the current NDVI is considered, but also the long-term historical data of NDVI, including the minimum and maximum values for the period of concern, to calculate the VCI value.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Vegetation Condition Index (VCI):

- ✓ It compares the current NDVI to a range of values observed in the same period in previous years

$$VCI_j = \frac{(NDVI_j - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \times 100\%$$

Where  $NDVI_j$  = NDVI for  $j^{\text{th}}$  month or week

$NDVI_{min}$  = Long-term (e.g., 20 years) minimum NDVI for  $j^{\text{th}}$  month or week

$NDVI_{max}$  = Long-term (e.g., 20 years) maximum NDVI for  $j^{\text{th}}$  month or week

VCI (%)	Drought class
< 10%	Extreme drought
10-20%	Severe drought
20-35%	Moderate drought
35-50%	No drought
> 50%	Wet



It is expressed in percentage, as we have seen, and provides insight into where the observed value stands between the extreme values of minimum and maximum from previous years. If the VCI is 0, it indicates poor vegetation health, signifying an extremely dry month. At 50 percent, it suggests fair vegetation, while at 100 percent, it indicates optimal vegetation. This provides insight into the health of plants or vegetation in a particular area. VCI focuses on the impact of drought on vegetation and can provide information on the onset, duration, and severity of drought by observing vegetation changes and comparing them with historical values. By analysing week-by-week data alongside historical data, one can gain a fair idea about the likely onset of the monsoon, the duration, and the severity of drought. All this information can be obtained through long-term analysis.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Vegetation Condition Index (VCI):

- ✓ The VCI is expressed in % and gives an idea where the observed value is situated between the extreme values (minimum and maximum) in previous years

VCI = 0: poor vegetation (extremely dry month/week)

VCI = 50%: Fair vegetation

VCI = 100%: Optimal vegetation

- ✓ It focuses on the impact of drought on vegetation and can provide information on the onset, duration, and severity of drought by noting vegetation changes and comparing them with historical values



The advantages of VCI include its high resolution and good spatial coverage. It can be used for crop field forecasting and long-term monitoring of vegetation health trends. This is crucial for understanding the impact of climate change, land use changes, and other factors on ecosystems over extended periods. By analysing historical data, one can observe trends in vegetation health in a given area. This allows for an assessment of the impact of climate change or land use changes in that area, as well as any significant changes in the ecosystem over an extended period of time. Typically, the curve you observe is yield versus VCI, where a higher VCI indicates higher crop yield, while a lower VCI suggests lower crop yield. However, it's important to note that some VCI models may use a limited number of spectral bands, which can constrain the ability to distinguish between different vegetation types or conditions accurately. Therefore, caution must be exercised when selecting the data used to calculate the VCI.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

**Vegetation Condition Index (VCI):**

- **Advantage:**
  - ✓ It has a high resolution and good spatial coverage
  - ✓ It can be used for crop yield forecasting
  - ✓ VCI can be used for long-term monitoring of vegetation health trends. This is crucial for understanding the impact of climate change, land use changes, and other factors on ecosystems over extended periods
- **Disadvantage:**
  - ✓ Some VCI models may use a limited number of spectral bands, which can constrain the ability to distinguish between different vegetation types or conditions accurately





Let's take an example: the long-term maximum and minimum NDVI values for August are 0.75 and 0.03, respectively. The average NDVI for the month is 0.35. Now, let's calculate the Vegetation Condition Index (VCI) and comment on the drought situation. The given NDVI value for August is 0.35, and the long-term maximum and minimum NDVI values for August are given as 0.75 and 0.03, respectively.

## Drought Indices

### Vegetation Condition Index (VCI)

#### Example 2

Long-term (25 years) maximum and minimum NDVI for August are 0.75 and 0.03. The average NDVI for the month is 0.35. Calculate the Vegetation condition index (VCI) and comment on drought.

#### Solution

Given,

- NDVI for August ( $NDVI_j$ ) = 0.35
- Long-term (25 years) maximum NDVI for August ( $NDVI_{max}$ ) = 0.75
- Long-term (25 years) minimum NDVI for August ( $NDVI_{min}$ ) = 0.03

Now, we can use the formula to calculate the Vegetation Condition Index (VCI). By substituting the NDVI value for August and the minimum and maximum values for August into the formula, we can calculate the VCI value, which turns out to be 44.44 percent. This indicates a no-drought condition, as the VCI value falls within this range. Therefore, based on the NDVI of the month and the long-term data, we conclude that there is no drought in the area under consideration. This serves as an important indicator.

## Drought Indices

### Vegetation Condition Index (VCI)

#### Solution

- Vegetation condition index (VCI) can be calculated as,

$$VCI_j = \frac{(NDVI_j - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \times 100\%$$
$$VCI = \frac{(0.35 - 0.03)}{(0.75 - 0.03)} \times 100\% = 44.44\%$$

- Since VCI is between 35% and 50%, there is no drought condition in the area

VCI (%)	Drought class
< 10%	Extreme drought
10-20%	Severe drought
20-35%	Moderate drought
35-50%	No drought
> 50%	Wet

Moving on to the next index, the Temperature Condition Index (TCI). It is used to determine the stress on vegetation caused by temperature extremes. The formula used for TCI involves BT, which represents brightness temperature, and VT, which is the brightness temperature for a specific year, month, or week. BT min and BT max are the long-term minimum and maximum

brightness temperatures for that particular month. Instead of NDVI, brightness temperature is used in this formula. Based on the TCI value, different conditions can be determined. If it is 0, it indicates an extreme condition, near to 0 suggests a severe condition, 0 to less than 100 indicates a moderate condition, and near to 100 suggests an optimal condition. Naturally, 100 percent represents the best condition, and the closer one is to 100, the better the conditions. Conversely, the closer one is to 0, the more severe the conditions are, potentially ranging from severe to extreme.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

❑ **Temperature Condition Index (TCI):**

✓ It is used to determine the stress on vegetation caused by temperature and excessive wetness


$$TCI_{max} = \frac{(BT_{max} - BT_j)}{(BT_{max} - BT_{min})} \times 100\%$$

Where,  $BT_j$  = Brightness temperature for  $j^{th}$  month or week

$BT_{min}$  = long term (e.g., 20 years) minimum BT for  $j^{th}$  month or week

$BT_{max}$  = long term (e.g., 20 years) maximum BT for  $j^{th}$  month or week

TCI (%)	Drought class
0	Extreme condition
near to zero	Severe condition
> 0 to < 100	Moderate condition
near to 100	Optimal condition



Let's consider an example, Example 3, where the long-term maximum and minimum brightness temperatures for May are 45 degrees Celsius and 32 degrees Celsius, respectively. The average brightness temperature for that month is 39 degrees Celsius. Now, let's calculate the Temperature Condition Index (TCI) and comment on the drought situation. Given that the brightness temperature for May is 39 degrees Celsius, the long-term maximum BT is 45 degrees Celsius, and the long-term minimum BT is 32 degrees Celsius.

## Drought Indices

### Temperature Condition Index (TCI)

#### Example 3

Long-term (25 years) maximum and minimum Brightness temperatures for May are 45°C and 32°C. The average Brightness temperature for that month is 39°C. Calculate the Temperature condition index (TCI) and comment on the drought situation.

#### Solution

- Brightness temperature for May ( $BT_j$ ) = 39°C
- Long-term (25 years) maximum Brightness temperature for May ( $BT_{max}$ ) = 45°C
- Long-term (25 years) minimum Brightness temperature for May ( $BT_{min}$ ) = 32°C

We can plug these values into the formula to calculate the TCI value, which turns out to be 46.15 percent. This places us somewhere in between, indicating a moderate drought condition. However, it's a position of caution, as we are hovering between drought and normal conditions. This demonstrates the value of TCI in providing insights into drought conditions.

## Drought Indices

### Temperature Condition Index (TCI)

#### Solution:

- Temperature condition index (TCI) can be calculated as

$$TCI_{max} = \frac{(BT_{max} - BT_j)}{(BT_{max} - BT_{min})} \times 100\%$$

$$TCI = \frac{(45 - 39)}{(45 - 32)} \times 100\% = 46.15\%$$

- So, there is moderate drought condition as the TCI is between 0 and 100%

TCI (%)	Drought class
0	Extreme condition
near to zero	Severe condition
> 0 to < 100	Moderate condition
near to 100	Optimal condition

Moving on to the advantages of TCI, it can serve as an early warning system for potential crop stress. Integrating thermal information with spectral data enhances our understanding of vegetation responses to both temperature and moisture conditions. Therefore, TCI can be applied for seasonal monitoring of temperature conditions, allowing for a better analysis of the impact of temperature on vegetation. However, there are some disadvantages to consider. Variations in atmospheric conditions can affect the thermal infrared signal received by remote



sensing instruments, impacting the accuracy of TCI. Additionally, surface characteristics such as soil type and moisture content can influence land surface temperature. These factors are important to consider, as they can affect the reliability of TCI readings. This drawback is typical for any remote sensing measurement.

**Drought Indices**

**Remote-sensing-based Agricultural Drought Indices**

☐ **Temperature Condition Index (TCI):**

- **Advantages:**
  - ✓ TCI values can serve as an early warning system for potential crop stress
  - ✓ The integration of thermal information with spectral data enhances the understanding of vegetation responses to both temperature and moisture conditions
  - ✓ TCI can be applied for seasonal monitoring of temperature conditions
- **Disadvantages:**
  - ✓ Variations in atmospheric conditions can affect the thermal infrared signal received by remote sensing instruments, impacting the accuracy of TCI values
  - ✓ Surface characteristics, such as soil type and moisture content, can influence land surface temperature

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Logos: IIT Bombay, IIT Madras, IIT Kharagpur, IIT Gandhinagar, IIT Roorkee, IIT Hyderabad, IIT Patna, IIT Varanasi, IIT Jodhpur, IIT Guwahati, IIT Tirupur, IIT Palakkad, IIT Mandla, IIT Durgam, IIT Bhilai, IIT Raipur, IIT Gandhinagar, IIT Patna, IIT Varanasi, IIT Jodhpur, IIT Guwahati, IIT Tirupur, IIT Palakkad, IIT Mandla, IIT Durgam, IIT Bhilai, IIT Raipur

Now, let's move on to DVI. DVI is probably the simplest vegetation index. DVI, or Difference Vegetation Index, is commonly used to assess vegetation health and monitor changes in plant cover over time. It is expressed as the difference between near infrared and red wavelengths, given by  $DVI = NIR - red$ . Currently, modified cameras or GoPros are being utilized to produce a simple Difference Vegetation Index, making it easy to obtain and providing a general idea of vegetation health, as visible light wavelengths are not reflected nearly as much as near infrared.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Difference Vegetation Index (DVI)

- ✓ Probably the simplest vegetation index
- ✓ It is commonly used to assess vegetation health and monitor changes in plant cover over time
- ✓ DVI is expressed as the difference between near-infrared and red wavelengths

$$DVI = NIR - Red$$

- ✓ Currently, modified cameras or GoPros are being used to produce a simple Difference Vegetation Index (DVI)
- ✓ DVI can give a general idea of the vegetation health as any visible light wavelength is not reflected nearly as much as near-infrared

The advantages of DVI include its sensitivity to vegetation changes, particularly in distinguishing between healthy and stressed vegetation, which is crucial for assessment purposes. Calculating DVI is straightforward, as seen from the relationship formula. However, DVI is sensitive to atmospheric conditions, such as clouds, aerosols, and water vapor, like many vegetation indices. Additionally, susceptibility to soil background influence may impact DVI results. Variations in soil properties can influence reflectance in red and near infrared bands, potentially leading to misinterpretation of vegetation conditions. Therefore, soil background and atmospheric conditions should be considered when interpreting DVI results, although these challenges are typical for many remote sensing-based calculations. So, one advantage of DVI is its simplicity, as it is usually based on a straightforward calculation.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Difference Vegetation Index (DVI)

##### • Advantages

- ✓ Sensitive to Vegetation Changes: DVI is particularly sensitive to changes in vegetation health and helps in distinguishing between healthy and stressed vegetation
- ✓ Simple Calculation: The calculation of DVI is relatively simple compared to some other vegetation indices, making it computationally efficient and easy to implement

##### • Disadvantages

- ✓ Sensitivity to Atmospheric Conditions: Like many vegetation indices, DVI can be sensitive to atmospheric conditions such as clouds, aerosols, and water vapour
- ✓ Susceptibility to Soil Background Influence: DVI may be affected by variations in soil properties, which can impact the reflectance in the red and near-infrared bands, potentially leading to misinterpretations of vegetation conditions

Moving on, let's discuss the Soil Adjusted Vegetation Index (SAVI), which attempts to minimize soil brightness influences by incorporating a soil brightness correction factor. As we've seen in previous examples, soil brightness presents a challenge, and SAVI addresses this issue by introducing a correction factor. This index is often utilized in arid regions where vegetation cover is low. SAVI is calculated using the relationship  $SAVI = (NIR - R) / (NIR + R + L * (1 + L))$ , where NIR represents pixel values for the near infrared, R represents pixel values for red, and L denotes the amount of green vegetation cover. The value of L varies depending on the amount of green vegetation cover present in the area. For areas with no green vegetation cover, L is 1; for areas with moderate green vegetation cover, L is 0.5; and for areas with very high vegetation cover, L is 0, equivalent to the NDVI method. Thus, the correction factor L is essential in the SAVI calculation.

**Drought Indices**

**Remote-sensing-based Agricultural Drought Indices**

- ❑ **Soil Adjusted Vegetation Index (SAVI)**
- ✓ The Soil-Adjusted Vegetation Index (SAVI) is a vegetation index that attempts to minimise soil brightness influences using a soil-brightness correction factor. This is often used in arid regions where vegetative cover is low.

$$SAVI = ((NIR - Red) / (NIR + Red + L)) \times (1 + L)$$

Where, NIR = pixel values from the near infrared band, Red = pixel values from the near-red band, and L = amount of green vegetation cover

- ✓ The L value varies depending on the amount of green vegetative cover. Generally, in areas with no green vegetation cover, L=1; in areas of moderate green vegetative cover, L=0.5; and in areas with very high vegetation cover, L=0 (which is equivalent to the NDVI method)

One advantage of SAVI is the reduced influence of soil background, addressing a drawback observed in earlier methods such as DVI or TCI. This correction factor allows for a more accurate assessment of vegetation health by minimizing the impact of soil brightness on the index values. So, by incorporating a soil adjustment factor into the formula, SAVI attempts to compensate for varying soil conditions in different areas, making it more reliable in situations where soil effects can be significant. This leads to improved accuracy, especially in areas with high vegetation cover, where other indices might encounter issues. However, a disadvantage of SAVI is its dependence on the soil adjustment factor. If this factor is not properly determined or if there are uncertainties in soil information, it can impact the reliability of the index values and their interpretation. Additionally, SAVI remains sensitive to soil type despite aiming to reduce the influence of soil background, presenting a challenge in its application across different soil types.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### ❑ Soil Adjusted Vegetation Index (SAVI)

##### • Advantages

- ✓ Reduced Soil Background Influence: By incorporating a soil adjustment factor in the formula, SAVI attempts to compensate for the varying soil contributions in different areas, making it more reliable in situations where soil effects can be significant
- ✓ Improved Accuracy in High Vegetation Cover Areas: SAVI is known for its better performance in areas with high vegetation cover, where other indices might face saturation issues

##### • Disadvantages

- ✓ Dependence on the Soil Adjustment Factor: If the soil adjustment factor is not properly determined or if there are uncertainties in soil information, it can impact the reliability of SAVI values and their interpretation
- ✓ Sensitivity to Soil Type: While SAVI aims to reduce the influence of soil background, it may still be sensitive to variations in soil types.

Moving on, let's discuss the Vegetative Atmospheric Registration Index (VARI), an RGB-based crop index commonly used for vegetation analysis using only RGB cameras. This means that even drones can be utilized for data collection. VARI reduces atmospheric effects by subtracting the blue wavelength from the sum of green and red wavelengths, calculated as  $(R_{green} - R_{red}) / (R_{green} + R_{red} - R_{blue})$ .

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### ❑ Visible Atmospheric Resistant Index (VARI)

- ✓ VARI is an RGB-based crop index
- ✓ It is one of the most commonly used indices for collecting vegetation data by utilising only RGB cameras
- ✓ VARI reduces the atmospheric effects by subtracting the blue wavelength from the  $(R_{green} + R_{red})$
- ✓ It is expressed as,

$$VARI = \frac{(R_{green} - R_{red})}{(R_{green} + R_{red} - R_{blue})}$$

This index is sensitive to vegetation health and performs well in detecting changes in vegetation conditions such as stress or growth. Moreover, it minimizes the impact of atmospheric conditions on remote sensing signals, allowing for a more accurate assessment of vegetation. The disadvantages include sensitivity to atmospheric conditions. Therefore, it may not adequately resist atmospheric effects, which could be a drawback. Additionally, its dependency

on specific sensor characteristics limits its application to only RGB cameras. Hence, VARI, or Variable Atmospheric Resistance Index, can only be used with RGB data; other types of data such as thermal cannot be utilized with this index.

**Drought Indices**  
**Remote-sensing-based Agricultural Drought Indices**

☐ **Visible atmospheric resistant index (VARI)**

- **Advantages**
  - ✓ **Sensitivity to vegetation health:** Being sensitive to changes in vegetation conditions, such as stress or growth, it performs well.
  - ✓ **Minimisation of atmospheric effects:** It minimises the impact of atmospheric conditions on the remote sensing signal, allowing for a more accurate assessment of vegetation
- **Disadvantages**
  - ✓ **Sensitivity to atmospheric conditions:** The index is not adequately resistant to atmospheric effects
  - ✓ **Dependency on specific sensor characteristics:** Its application is limited to data from RGB camera

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Small video inset showing a man speaking.

Logos of institutions at the bottom.

Now, let's discuss the last index, the Green Vegetation Index (GVI), also known as the Lancet TM TESEL CAP Green Vegetation Index. This index minimizes the effects of background soil while emphasizing green vegetation. It utilizes global coefficients to transform pixel values and generate new bands. Initially designed for use with Lancet TM data, it also works with corresponding bands of Lancet ETM Plus or Lancet 8 satellites, which are more modern. GVI can be calculated using the relationship where TM1 to TM7 refer to Lancet thematic mapper bands. These bands cover the entire Lancet TM spectrum, and the index value ranges from -1 to 1.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Green Vegetation Index (GVI)

- ✓ Also known as the "Landsat TM Tasseled Cap Green Vegetation Index, GVI minimises the effects of background soil while emphasising green vegetation
- ✓ It uses global coefficients that weigh the pixel values to generate new transformed bands
- ✓ GVI was originally designed for use with Landsat TM, but it also works with the corresponding bands of Landsat ETM+ and Landsat 8

$$GVI = (-0.2848 \cdot TM_1) + (-0.2435 \cdot TM_2) + (-0.5436 \cdot TM_3) + (0.7243 \cdot TM_4) + (0.0840 \cdot TM_5) + (-0.1800 \cdot TM_7)$$

Where,  $TM_1$  to  $TM_7$  refer to Landsat TM bands.

- ✓ Its value ranges from -1 to 1

As for its advantages, GVI correlates well with ground truth data, ensuring reliability and accuracy. So, obviously, in any remote sensing-based analysis, we always use ground truth data. GVI has been found to work well with ground truth data, and simplicity and ease of interpretation are preferred for widespread use due to the ease of calculation and interpretation. One disadvantage includes a lack of sensitivity to specific vegetation stress factors. It may not be sensitive to specific stress factors affecting vegetation, such as nutrient deficiency or specific diseases. Additionally, over-reliance on the green band is a concern. GVI heavily depends on the green spectral band; thus, variations in atmospheric conditions or sensor characteristics affecting this band might impact the accuracy of the index. So, these are the advantages and disadvantages. However, a large number of remote sensing-based agricultural drought indices have been developed, and they are being used effectively.

## Drought Indices

### Remote-sensing-based Agricultural Drought Indices

#### □ Green Vegetation Index (GVI)

##### • Advantages

- ✓ Correlation with ground truth data: It matches ground truth data well to ensure reliability and accuracy
- ✓ Simplicity and ease of interpretation: It is preferred for widespread use due to ease of calculation and interpretation

##### • Disadvantages

- ✓ Lack of Sensitivity to Specific Vegetation Stress Factors: GVI may not be sensitive to specific stress factors affecting vegetation, such as nutrient deficiencies or specific diseases
- ✓ Over-reliance on Green Band: GVI heavily depends on the green spectral band; thus, variations in atmospheric conditions or sensor characteristics affecting this band might impact the accuracy of the index



With this, we come to the end of this lecture where we have introduced remote sensing-based agricultural drought indices, which are being used quite often nowadays because remote sensing data is now basically the "in" thing as far as research goes. That's why these indices are very popular. Please give your feedback and also raise any questions or doubts you may have; we shall be happy to answer on the forum. Thank you very much.

THANK YOU

