Graphical Analysis Approach

- Madhya Pradesh is a large geographical zone with various soils and climate where the soybean is grown between June (plantation) and November (harvest).
- Our analysis is based on 5 MODIS indicators : NVDI, LAI, ET, LST and RF recorded by district, month and year.

- To get relevant correlation between soybean yields and MODIS indicators, we divided Madhya Pradesh in 11 agro-climatic regions and made an entire graphical analysis based on the data specific to each regions by month and year.

MODIS INDICATORS

- NVDI , the Normalized Difference Vegetation Index, quantifies vegetation between -1 and 1 by measuring the difference between near-infrared and red light. It is a good indicator of crop health.

- LAI, Leaf Area Index , is calculated as half the area of all leaves per unit area of ground. It describes plant canopy structure from 0 to 9. A higher LAI corresponds to a better primary productivity.

- ET is the loss of water by evaporation or transpiration of the plant in mm/day.

- LST , the Land Surface Temperature is the radiative skin temperature of the land surface, as measured in the direction of the remote sensor.

- RF, Rainfall quantifies the amount of precipitations in centimeters.

Agroclimatic zones

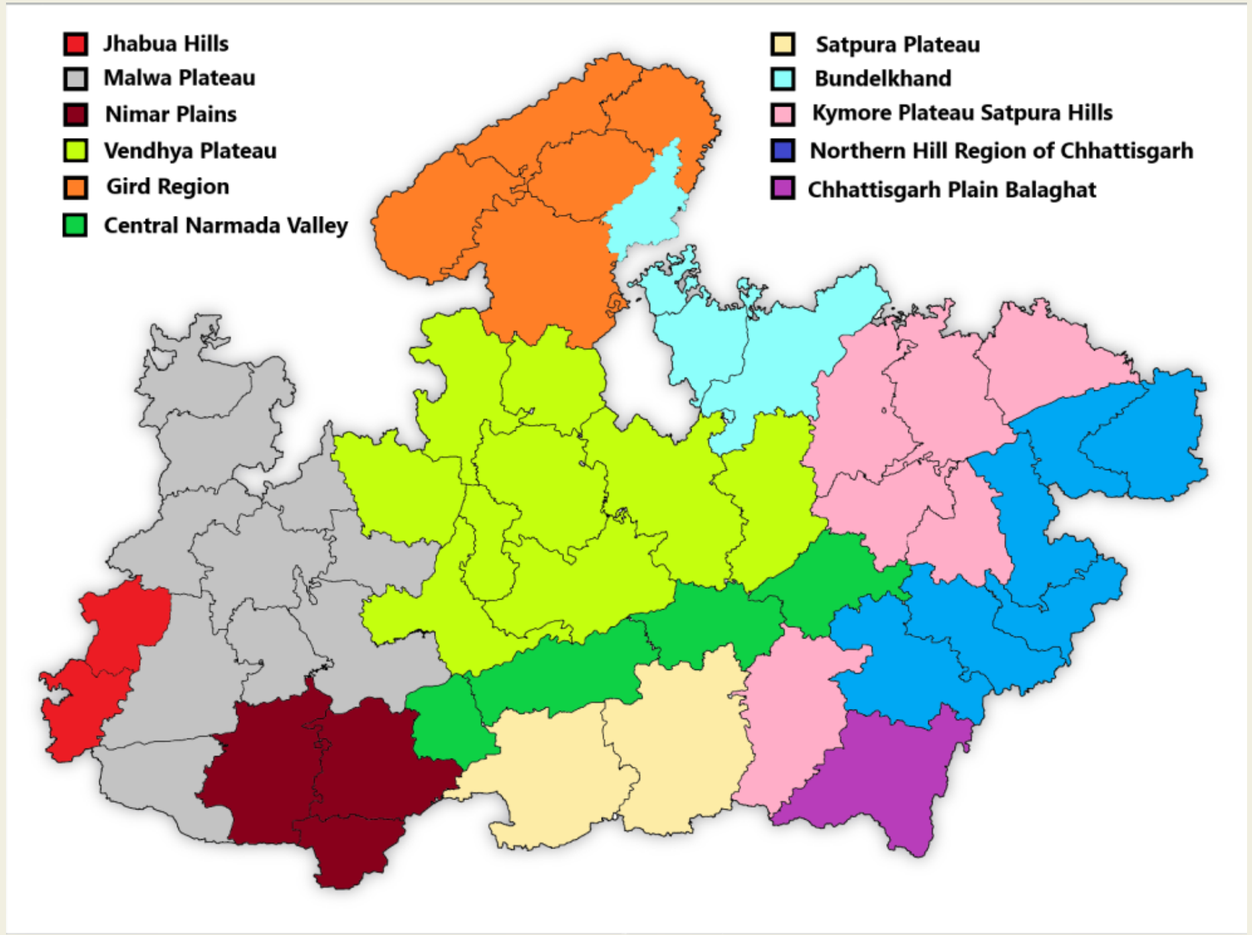
We can divide the Madhya Pradesh into 11 agroclimatic zones, which is easier to study than 46 districts. These zones share similar weather conditions and soils.

Each zone has a distinct set of available natural resources and limitations. The eastern region of the State is known for its rice-based farming systems and light alfisols, which have a low capacity to retain water, whilst other regions have soils with a very high water retention, as Black Cotton for the Vendhya Plateau.

Important soil types in various regions of the states include clay and clay loams and sandy loam soils (Bundelkhand), mixed red and black soil (Kymore plateau), medium and deep black (Vindhya plateau), or even deep black with clay (Central Narmada Valley).

You can find and download the data for the distribution of the 46 districts under the 11 zones on the Ocean Marketplace for free :

https://market.oceanprotocol.com/asset/did:op:26752ce2f1efbb1b78f04277b8bb39dea25e2b59634a2740aab713a1d400ef96



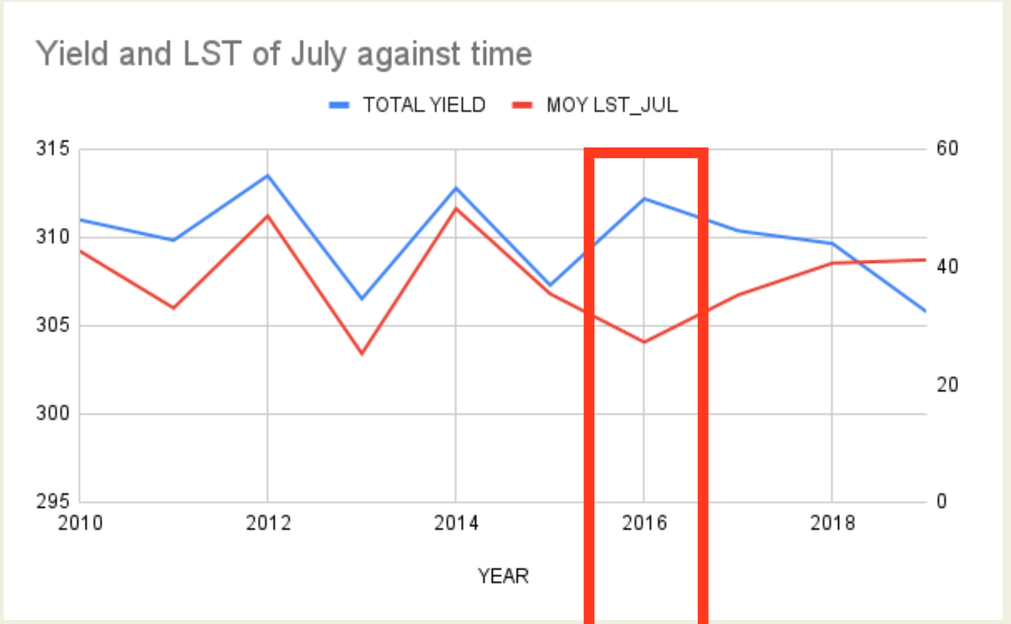
Graphical Analysis Findings

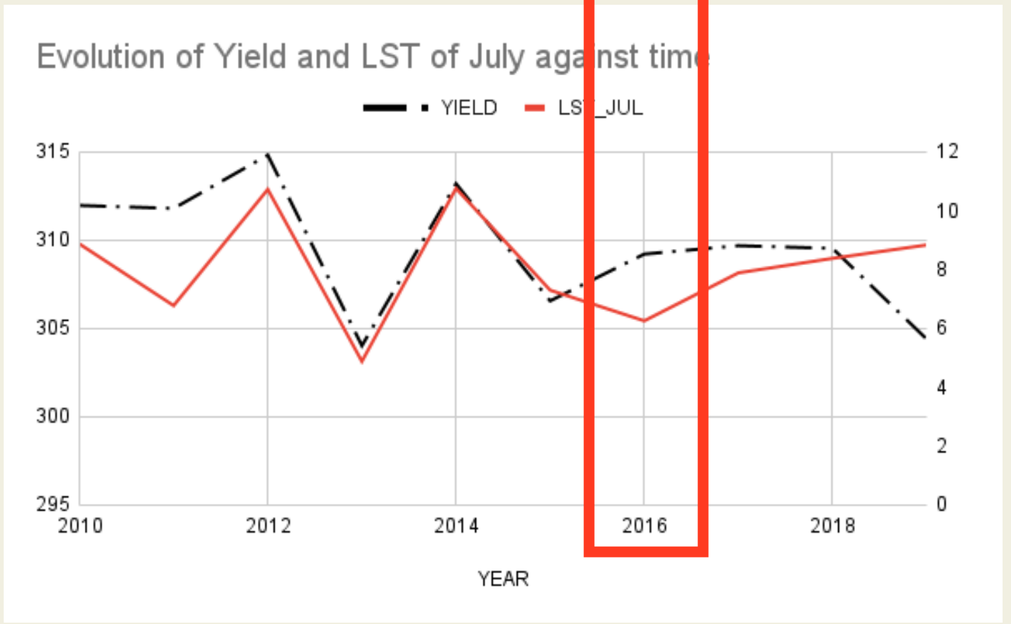
Land Surface Temperature (LST) is highly correlated to yields in every region studied.
Indeed, the LST curve of July is very similar to the yield curve against years for Madhya Pradesh. This relation is both remarkable through the Madhya Pradesh study (graph 1) and within each agro-climatic region. (graph 2, Vendhya Plateau).

As July corresponds to the beginning of the crop development, we can conclude that a higher mean temperature during this periods leads to a better performance of the soybean crops.

We notice that 2016 does not follow the same pattern. It can be explain by the exceptional meteorological conditions.

Observing more precisely the Land Surface Temperature during this crucial moment could be a good indicator and could lead to develop new technologies to cool down the the crops, with shades or natural methods (planting trees every now and then, alternating the crops with more dense crops...)





Graphical Analysis Findings

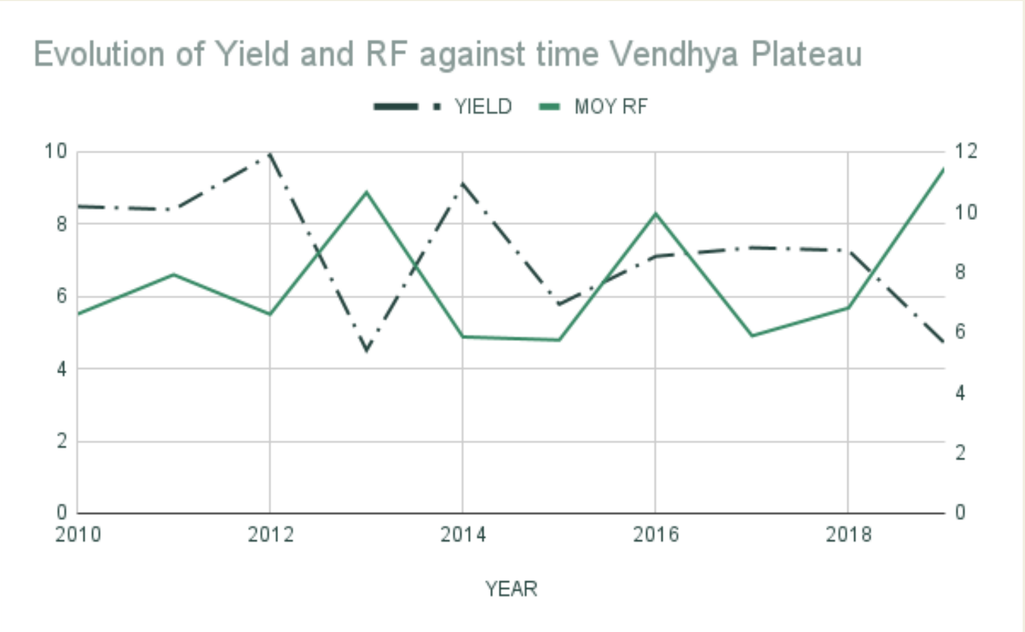
Rain fall is the second indicators impacting the yields of soybean.

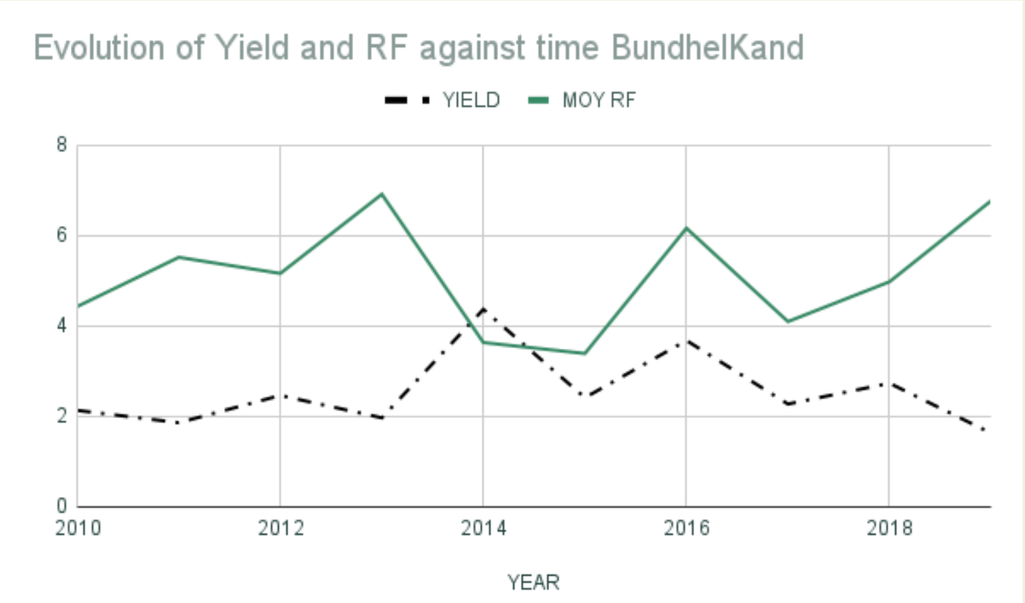
RF is inversely related to yield because too much moisture can result in plants more susceptible to disease and lodging at harvest. On the other hand, less water encourages plants to develop stronger, healthier root systems that grow deeper.

RF is highly inversely correlated to yields in Vendhya Plateau (graph 1), as well as in BundhelKand (graph 2).

It can be explained by the soil of these regions and of Madhya Pradesh in general. VP soils is mainly composed of black cotton, which is distinguished by high properties of shrinkage and swelling. It means that the soil retains too much water compared to the crops needs.

Evapotranspiration is related in the same way to yield. It is due to ET-RF relationship. Indeed, a higher quantity of rainfall means that the plants absorbs more water, and thus have more water to reject by evaporation or transpiration.





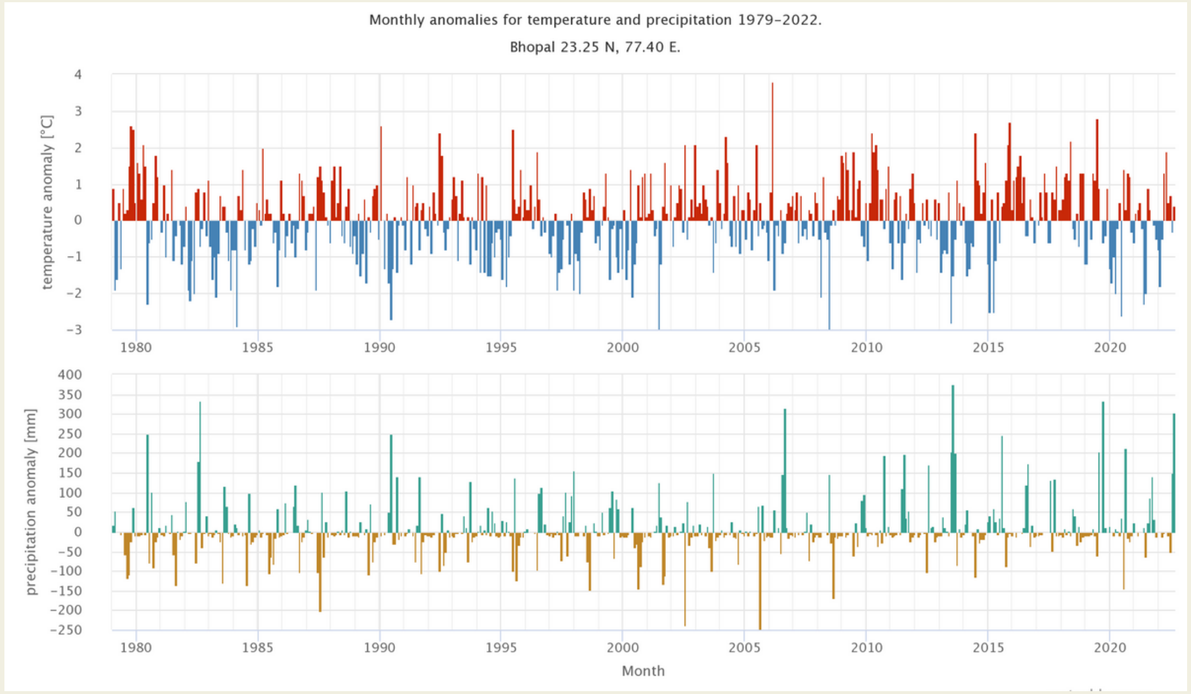
Additional data studies to explain variations in yield

As we can see in the first part, there are correlation beetween the different indicator and the yield, but also there are a lot of variation and "unexpected values".

The top graph depicts the monthly temperature anomalies in Bhopal, a district on the Vindhyan Plateau, from 1979 to the present. The anomaly indicates how much warmer or colder it was than the 30-year climatic mean between 1980 and 2010. As a result, the blue months were colder than usual while the red months were warmer.

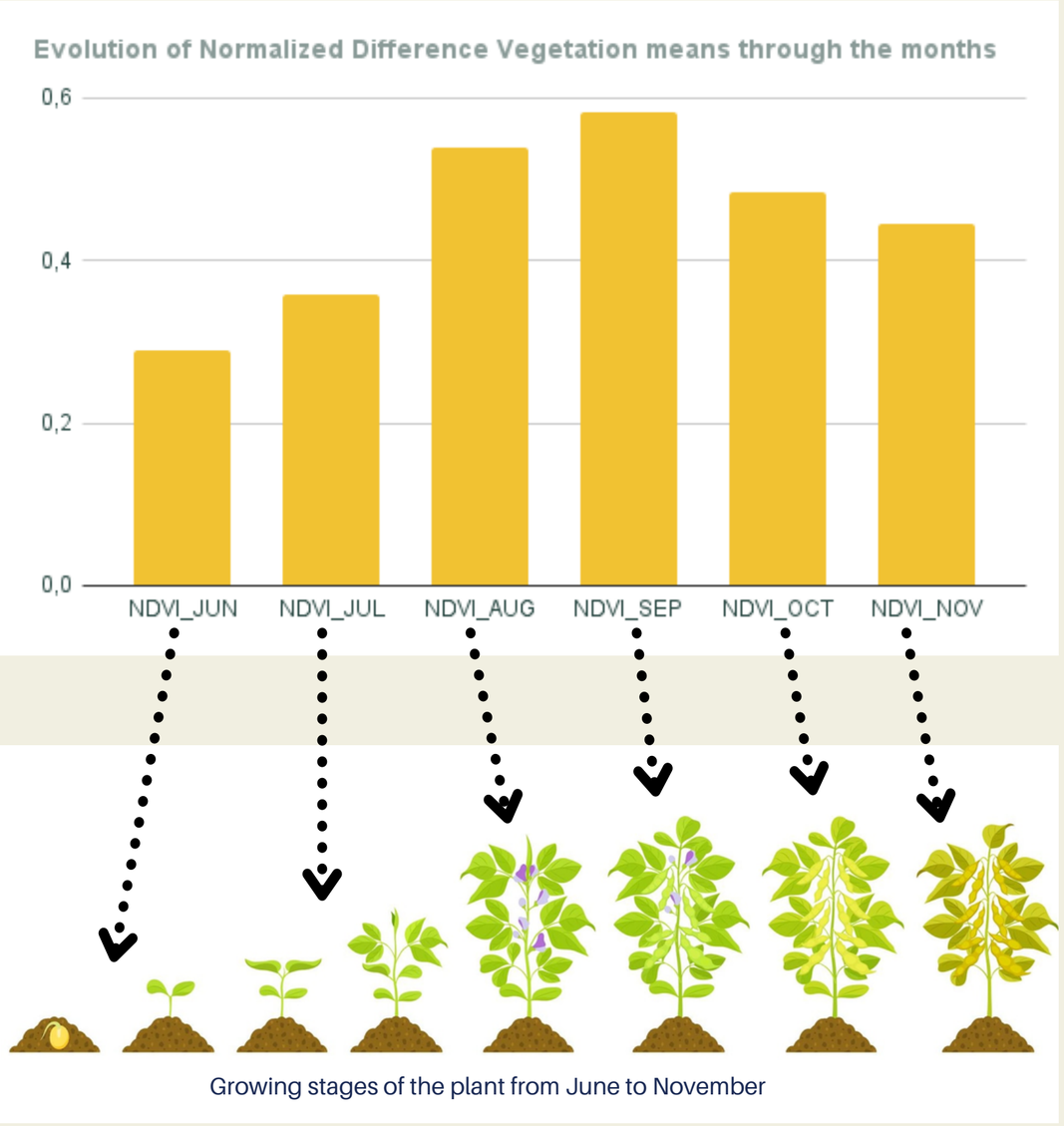
Most places have experienced an increase in warmer months over time, which is a reflection of the global warming brought on by climate change.

The lower graph is the same thing, for precipitation. There is a huge increase in the frequency and the scale of anormal rain, and this can lead to very bad yield as the crops get flooded.



Monthly anomalies for temperature and precipitations in Bhopal from 1979 to 2022

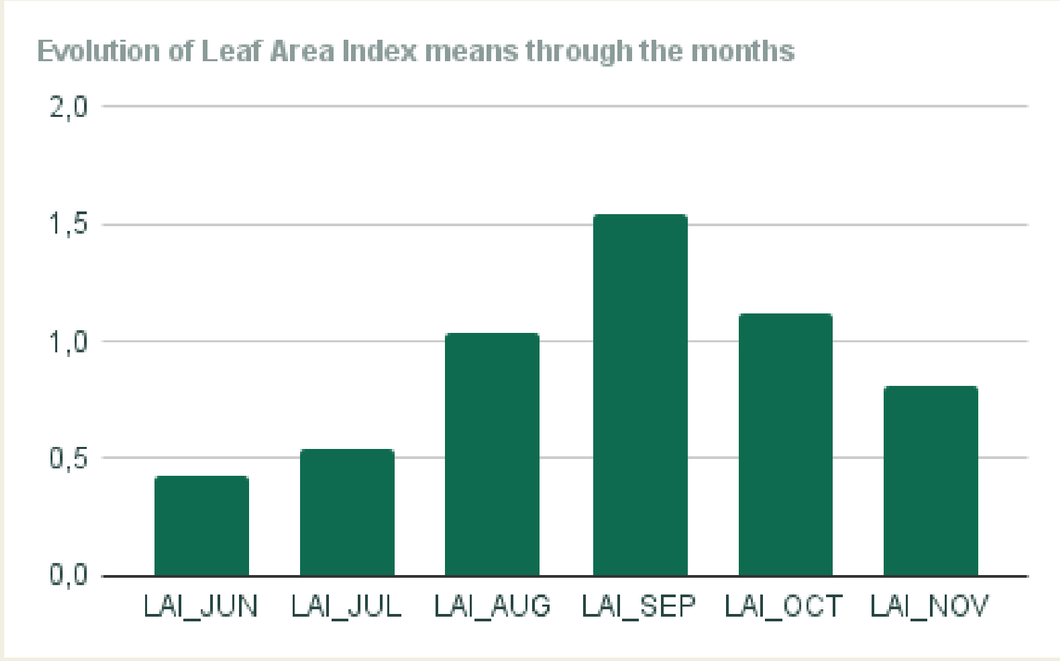
Time series analysis : NDVI and LAI



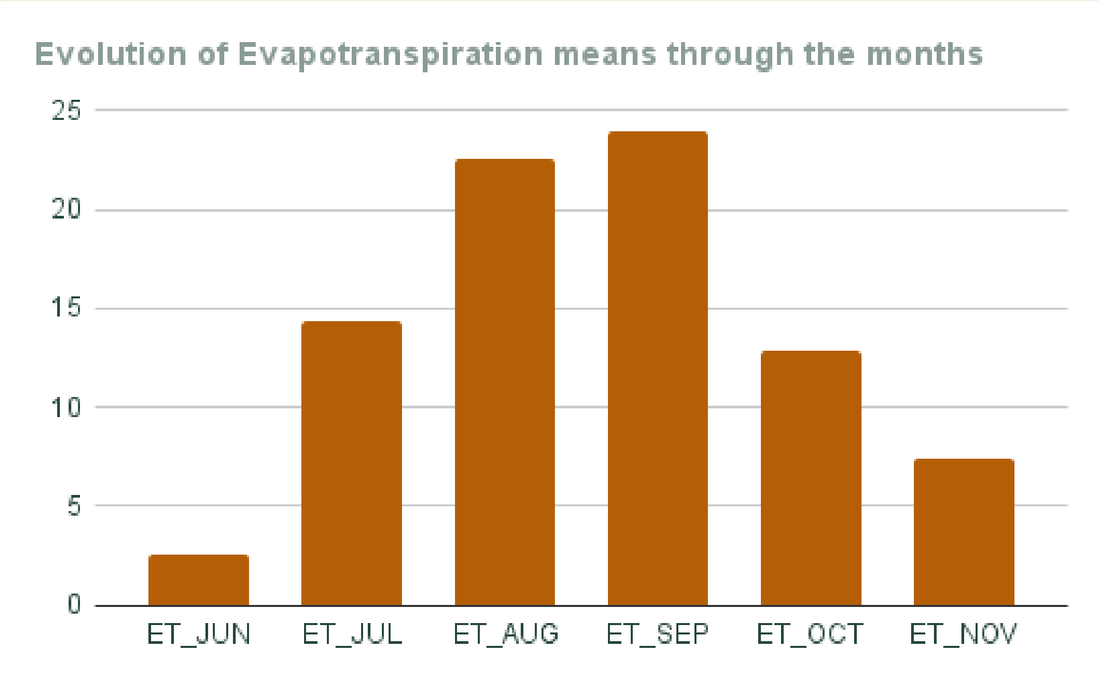
Growing stages of the plant from June to November

In terms of time series analysis, you can clearly see the correlation beetween NDVI and the months. It is normal, the plant goes through a few stages of growth before being mature and recolted in november. Having a good NDVI in August and September is a good indicator of a future good yield. The exact same thing goes when looking at LAI, the pattern the values follow are similar and it is also linked to the growth of the soybean crop.

The plant size could be a good indicator of the health of the future yields we study as well, and will still be highly correlated with these two indicators.

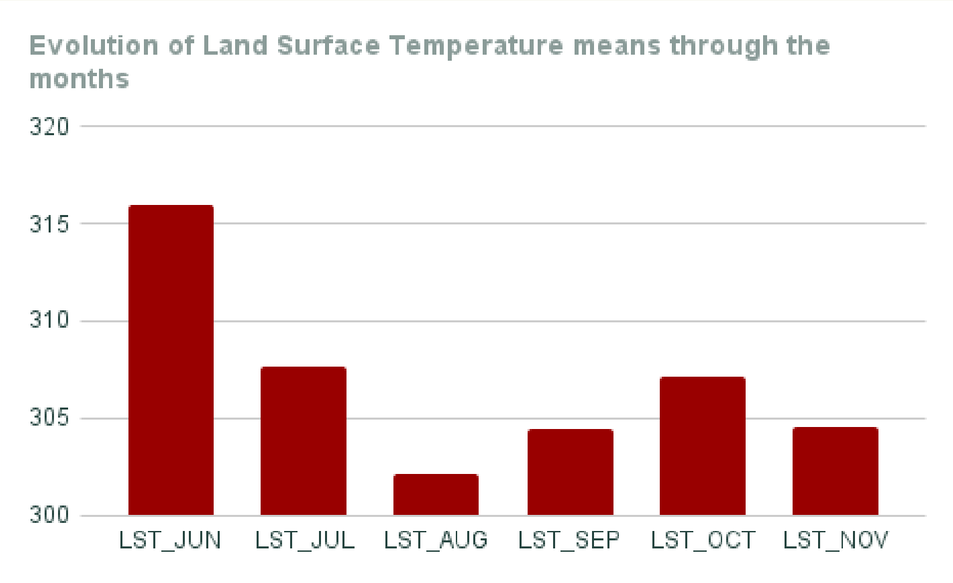


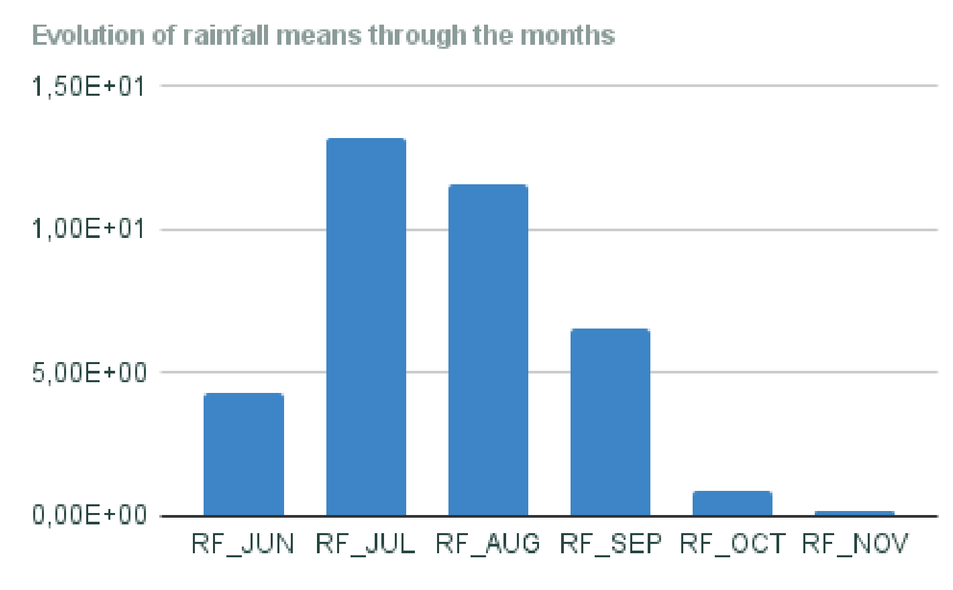
Time series analysis : Evapotranspiration

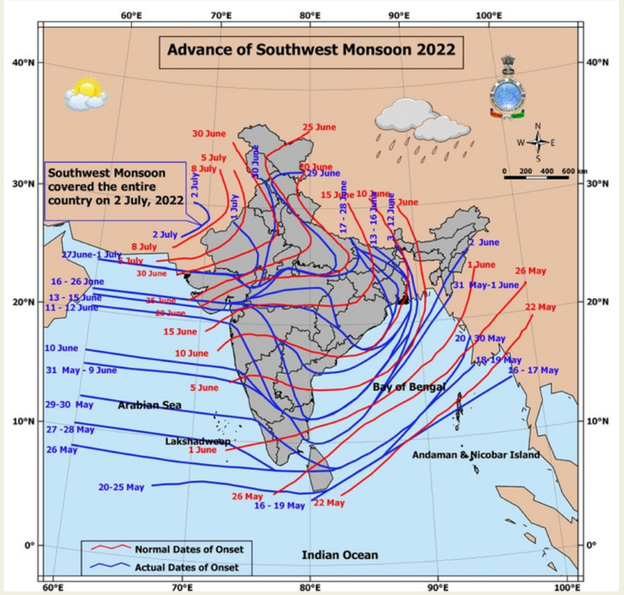


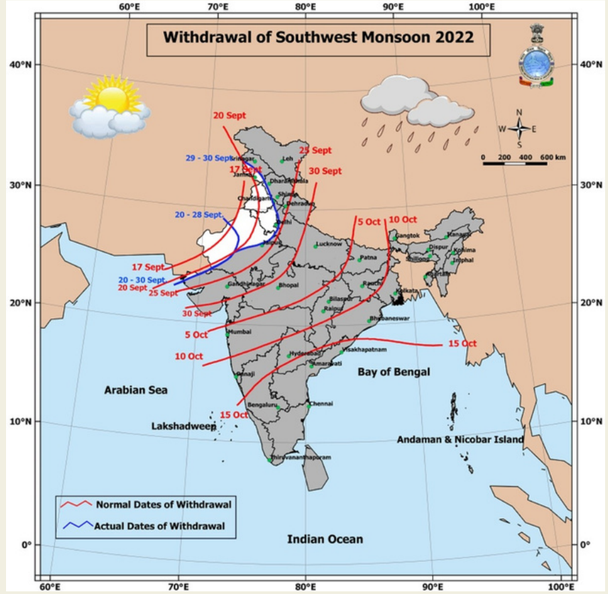
Evapotranspiration follows a similar pattern, as the plant grows she uses more water to stay alive and in good shape. But the high points starts earlier, in August, because it is the moment the plant uses a lot of water to grow to the maximum stage of development.

Time series analysis : Rainfall and LST







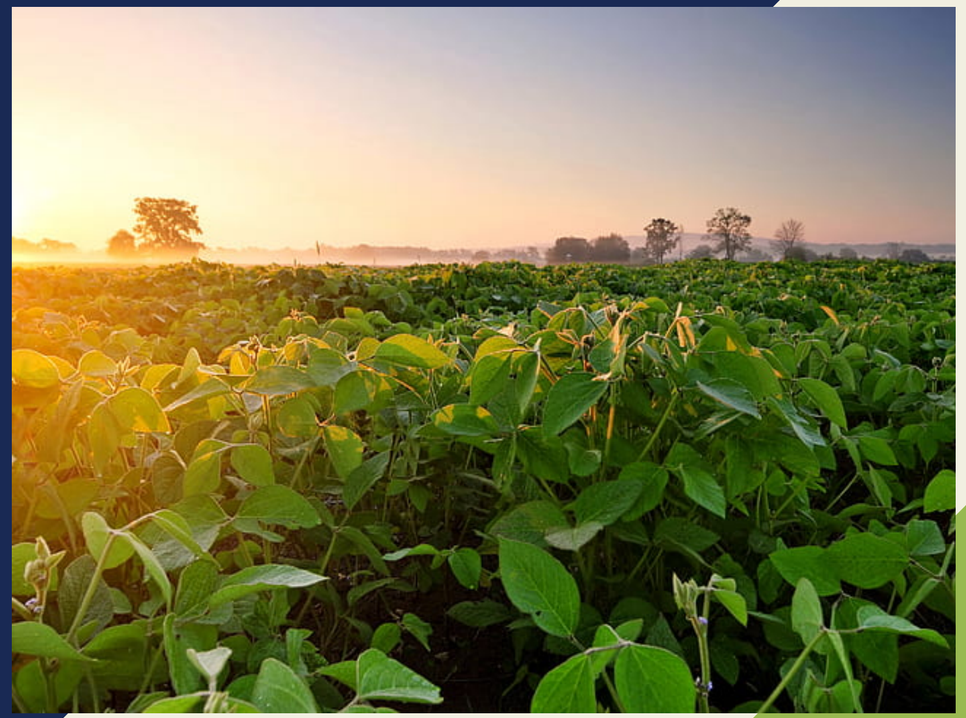


Advance (arrival) and withdrawal of Southwest Moonsoon in India in 2022
from the official India meteorological department, Ministry of Earth Sciences

The correlation beetween Rainfall and Land Surface Temperature is linked to the seasons in India. These two indicators are cyclic and can be studied per month over the 6 months growing period of soybean.

As we can clearly see on the graphs, the general temperatures decrease from their high point which is during Summer, that takes place from April to end of June / beginning of July.

The moonsoon is the rain season in India, and thus starting from July to the end of September/early October, the precipitations will be much higher than before.



Thank you for reading this report.

I hope you appreciate this work and I look forward to work on Phase 3.

Annexes index

01

Minimum requirement graphs :

Features (NDVI, LAI, ET, LST, RF) and the yearly yields versus time (10 years range).

02

Another study about the growth of climatic extreme events in India.

01 Minimum requirement graphs :

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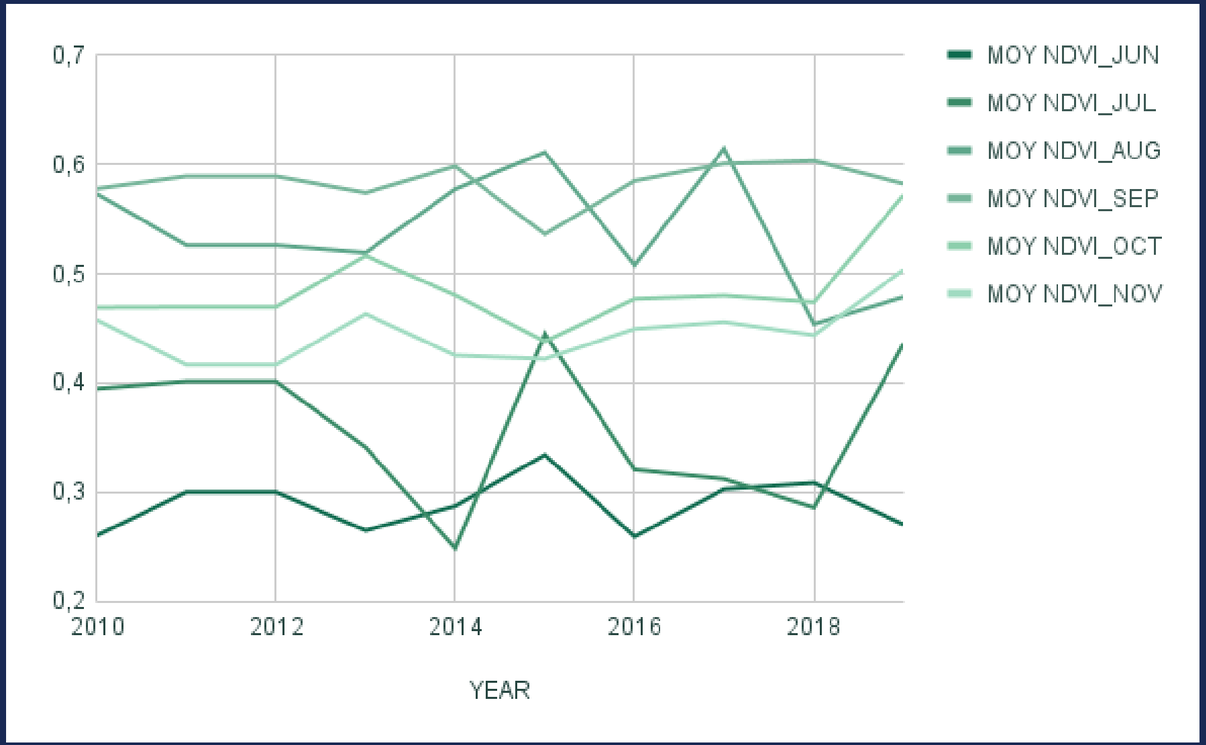

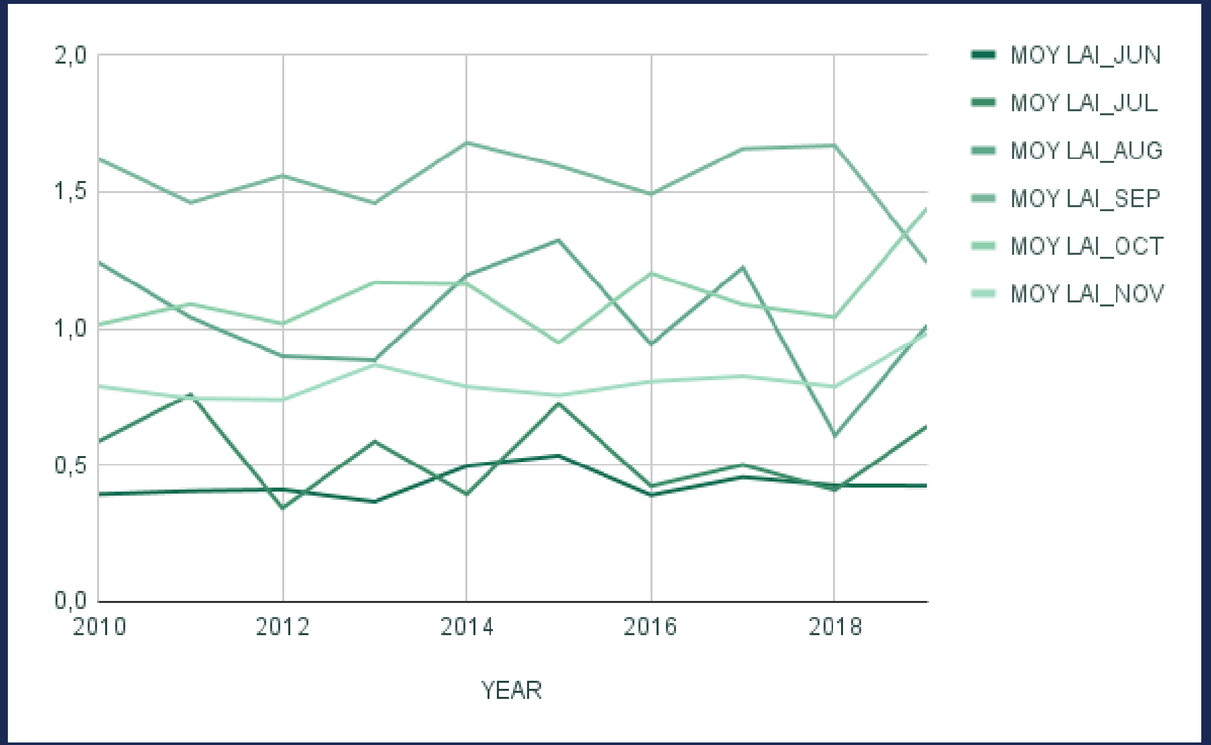

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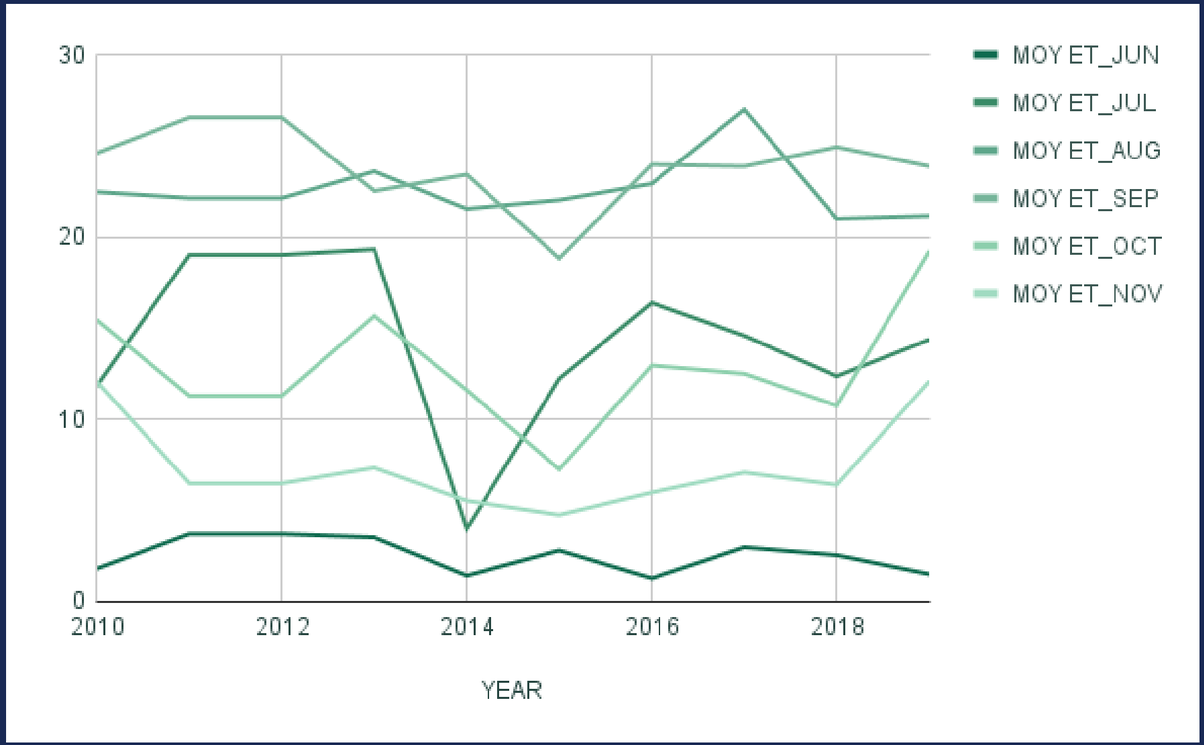

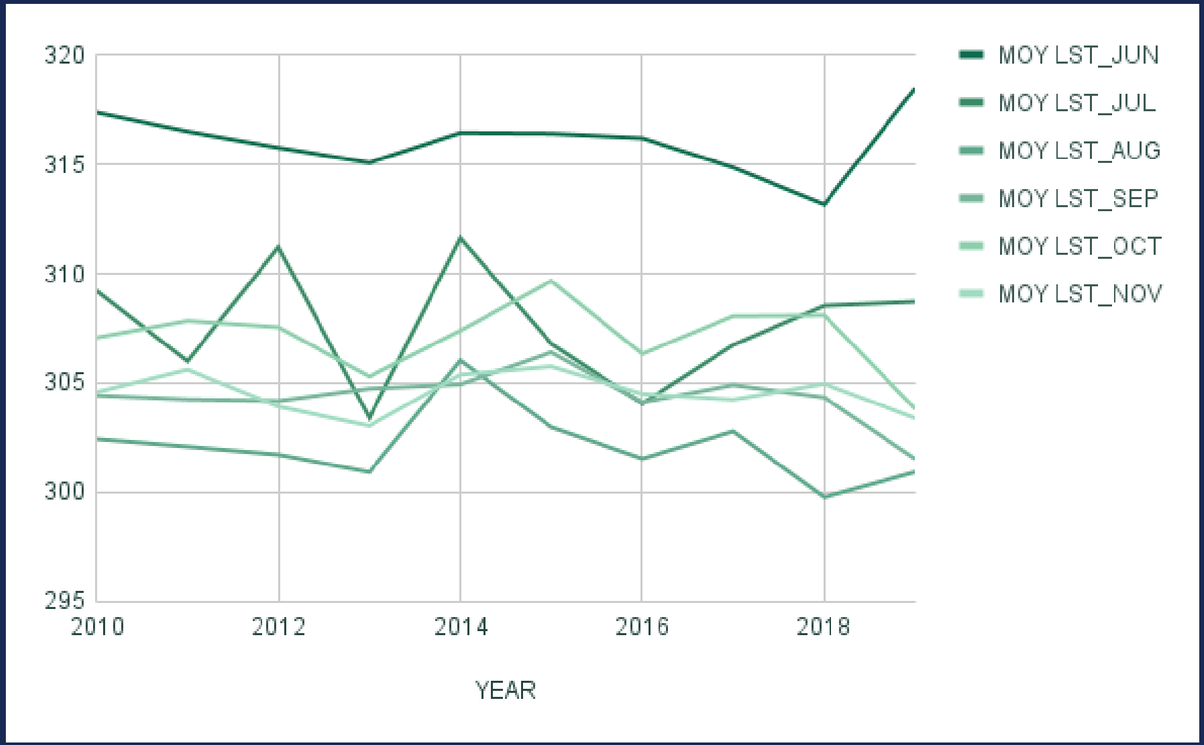

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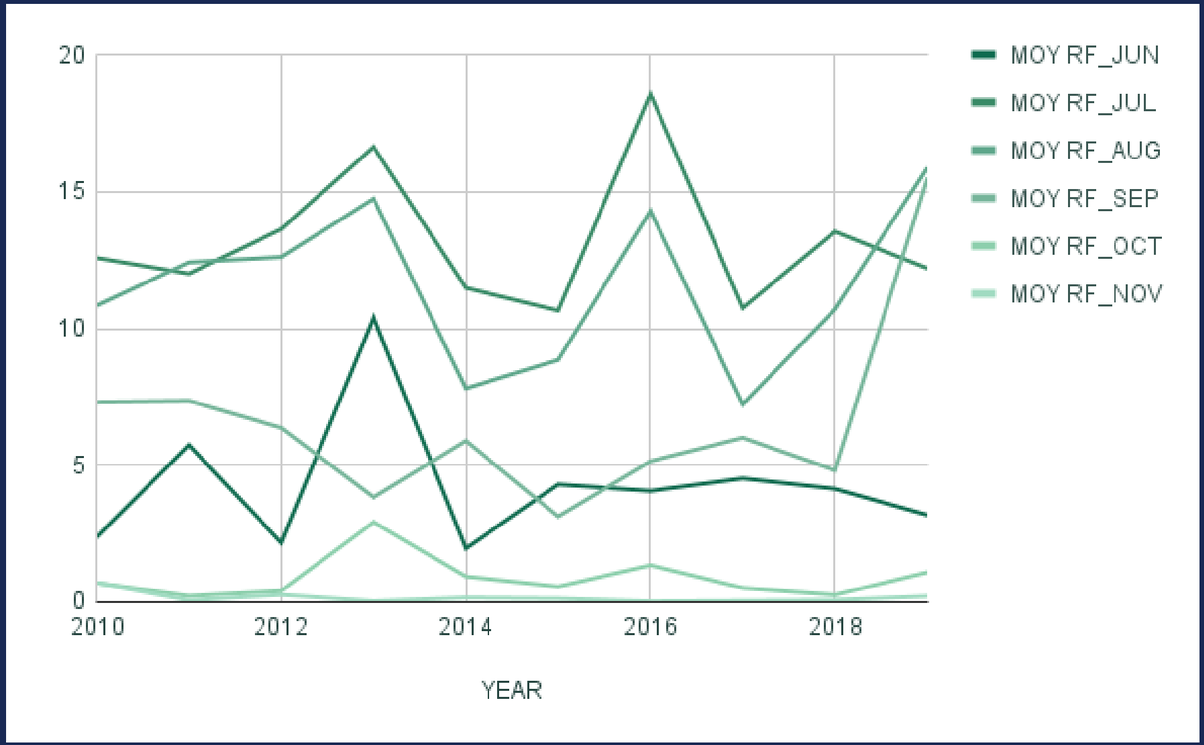


02

Another study about the growth of climatic extreme events in India.

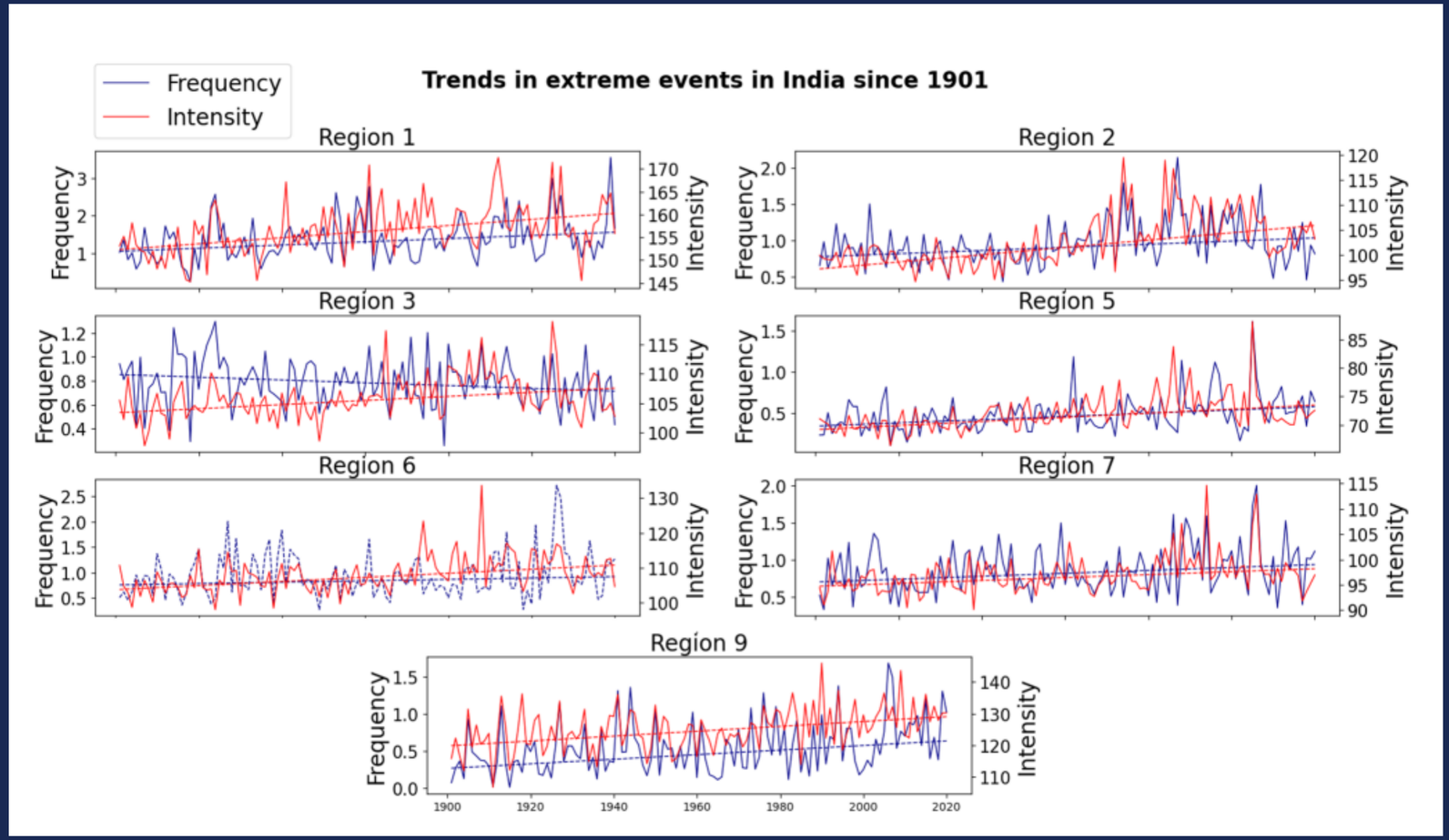
Another very interesting study to show the increase of extreme events in India. This is very concerning for the future of Soybean farming as we saw too much precipitation or too much heat have negative impacts on the yield.

The daily gridded rainfall dataset has been used to calculate the frequency of extreme events.

The number of grid cells where the daily rainfall surpassed this threshold has been counted for all of the monsoon seasons between 1901 and 2020 after the regional threshold was defined as the 99th percentile of the local monsoon rainfall distribution.

It has also been determined what the average intensity of these occurrences is.

This data and analysis is part of a scientific research report by Renaud Falga & Chien Wang.



Trends in frequency (blue) and intensity (red) in each region. The frequency of extremes is given in number of extreme events per monsoon season per grid cell, while the intensity is given in mm/day. The time series plotted in dashed line (frequency in region 6) correspond to a statistically insignificant trend (found by performing Mann–Kendall test at the 95% confidence level).