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Assessment of climatic impact on growth and production of rice (*Kharif*) and wheat (*Rabi*) using geospatial technology over Haryana

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सार — **वैश्विक जलवायु परिवर्तन का भारतीय कृषि पर काफी नकारात्मक प्रभाव पड़ सकता है और इसके अधिक सामान्य तथा गहन रूप से विकसित होने के परिणामस्वरूप खाद्‍य सुरक्षा हो सकता है। दरअसल, कृषि के विकास और उत्पादन पर मौसम की परिवर्तनशीलता की जांच हमेशा जटिल होती है। इस अध्ययन में वर्ष** 1991 **से** 2020 **तक की समयावधि के लिए वार्षिक और मासिक आधार पर कृषि के विकास और उत्पादन पर मौसम परिवर्तनशीलता के प्रभाव का मूल्यांकन विभिन्न मौसम चरों (न्यूनतम तापमान, अधिकतम तापमान, सापेक्ष आर्द्रता, पवन की गति और वर्षा), वनस्पति सूचकांक (एनडीवीआई और एलएआई) और फसल की उपज (गेहूं और चावल) के बीच पियर्सन सहसंबंध विश्लेषण द्‍वारा किया गया है। प्रारंभ में, भारत के हरियाणा राज्य में फसल की पैदावार के साथ-साथ दीर्घ अवधि** (1991-2020) **के लिए मासिक और वार्षिक समय पैमाने पर मौसम चरों और वनस्पति सूचकांकों के अस्थायी व्यवहार का पता लगाया गया है। उसके बाद कृषि पर दीर्घकालिक मौसम के प्रभाव के साथ-साथ एनडीवीआई-मौसम और एलएआई-मौसम के संबंध को समझने के लिए व्यक्तिगत रूप से मासिक और वार्षिक समय पैमाने पर मौसम चर, वनस्पति सूचकांक और फसल की उपज के बीच एक पियर्सन सहसंबंध विश्लेषण किया गया है। मासिक और वार्षिक आधार पर एनडीवीआई-मौसम और एलएआई-मौसम के बीच एक महत्वपूर्ण सहसंबंध पाया गया है। वर्ष** 1998-2018 **के दौरान भारत के हरियाणा राज्य में ख़रीफ़ ऋतु के दौरान तापमान, सापेक्ष आर्द्रता और वर्षा का सकारात्मक प्रभाव चावल की फसल के उत्पादन पर पाया गया है, जबकि हवा की गति ने चावल की फसल के उत्पादन पर नकारात्मक प्रभाव दिखाया है। गेहूं की फसल (रबी सीजन) के मामले में, न्यूनतम तापमान, वर्षा और सापेक्ष आर्द्रता गेहूं की फसल के उत्पादन में सहायता करती है, जबकि अधिकतम तापमान और हवा की गति ने वर्ष** 1998-2018 **के दौरान हरियाणा में गेहूं की उपज पर नकारात्मक प्रभाव दिखाया है। कुल मिलाकर, इस अध्ययन में गेहूं की फसल की उपज में लगभग** 0.044 **टन प्रति हेक्टेयर और चावल की फसल की उपज में** 0.029 **टन प्रति हेक्टेयर की वार्षिक वृद्धि पाई गई है।**

ABSTRACT. Global climate change could have a substantial negative influence on Indian agriculture and becoming more common and intense growing as a result of food security. Indeed, the examination of weather variability on agricultural growth and production is always complex. The weather variability impact on agricultural growth and production has been evaluated by Pearson correlation analysis among various weather variables (minimum temperature, maximum temperature, relative humidity, wind speed and rainfall), vegetation indices (NDVI and LAI) and crop yield (wheat and rice) on yearly and monthly basis for the time period from the year 1991 to 2020 in the present study. Initially, the temporal behavior of weather variables and vegetation indices have been explored on the monthly and yearly time scale for the long term (1991-2020) along with crop yield over Indian state of Haryana. After that a Pearson correlation analysis have been carried out among the weather variables, vegetation indices and crop yield on monthly and yearly time scale, individually to understand the relationship of NDVI-weather and LAI- weather along with the long-term weather impact on agricultural production. A significant correlation is found between NDVI- weather and LAI-weather on monthly and yearly basis. The positive impact of the temperature, relative humidity and rainfall is found on the rice crop production, while the wind speed showed the negative impact on the rice crop production during the *Kharif* season in Haryana state of India during the years 1998-2018. In case of wheat crop (*Rabi* season), the minimum temperature, rainfall and relative humidity supports the wheat crop production, while the maximum temperature and wind speed showed the negative impact on the wheat yield in Haryana during the years 1998-2018. Overall, this study has found the annual increase in wheat crop yield approximately 0.044 tons per hectare and rice crop yield 0.029 tons per hectare.

Key words – NDVI, LAI, Rice, Wheat, Yield and Weather.

1. Introduction

The world agricultural production increases in consistent manner during the previous 50 years and global food output has expanded at an unparalleled rate. Although some recent studies suggest that the decline in crop yields and uneven distribution over the globe. The weather condition is very important for Farmer livelihoods during crop growing season. Due to their poorer adaptation capacity and reliance on agriculture for basic staple crop production, nourishment and incomes, smallholder subsistence farmers in underdeveloped nations in Africa and Asia are disproportionately affected by weather shocks (Morton, 2007). The worldwide climate change scenario establishes a significant attention due to its meaningful long term impact on agricultural productivity over past decades. The United Nations Intergovernmental Panel on Climate Change (IPCC) report 2021 estimates that the world will probably reach or exceed 1.5 °C in next two decades (Atwoli *et al*., 2021; Molina and Abadal, 2021).

Several challenges are arising in the agricultural system and management due to the climate variability, extreme weather event, water scarcity, soil fertility and pollution level increases, which are responsible to uncertainty in yield and grain prices (Burney and Ramanathan, 2014; David *et al*., 2018; Gupta *et al*., 2017; Lobell *et al*., 2013). It necessary to ensure that food supply keep up with rising demand, it is vital to understand the processes involved in crop growth and development having substantial impact of weather variables like changes in temperature, precipitation and wind speed (Watson *et al*., 1996).

Chavas *et al*. (2009) studied the long-term climate change impacts on agricultural productivity in for baseline 1961-1990 and future 2071-2100 periods with the EPIC agro-ecosystem simulation model under A2 scenario conditions in eastern China. They found that the aggregate potential productivity increases 6.5% for rice, 8.3% for canola, 18.6% for corn, 22.9% for potato and 24.9% for winter wheat, with significant spatial variability for each crop.

Plant productivity will be impacted by the warmer temperatures projected as a result of climate change, as well as the potential for more extreme temperature events (Hatfield and Prueger, 2015).

In case of Indian context, there are several researchers have reported the weather impact on agricultural growth and yield for various economical crops like wheat, rice, sugarcane, maze, mustered, cotton, soyabean etc. over different states and districts (Birthal *et al*., 2014; Gupta *et al*., 2017; Mahdi *et al*., 2015; Mall *et al*., 2018; Mall *et al*., 2006; Singh *et al*., 2013; Talukder *et al*., 2014). Sonkar *et al*. (2019) studied the rising temperature and aerosol impact on the wheat yield during the years 1986-2015 over five wheat growing zones across India. They found that the one degree rises in average temperature reduce a 7% wheat crop yield across India. They also found a disproportionately variation in the reduction of wheat yield across the crop growing zones by a range of 9% (peninsular zone, PZ) to 4% (northern hills zone, NHZ). Dhamija *et al*. (2020) estimated wheat crop sensitivity to climate change using time, space and weighting approaches to account for heterogeneities in time, space and weighting methods. For this purpose, they quantify exposure to climatic risks, climate predictions were made under current conditions (1975-2005) and two projected Representation Concentration Pathways (RCPs), 4.5 and 8.5, for the years 2021-2050. The vulnerability profile indicates that the wheat crop in northern and central India is highly vulnerable.

There are several global efforts have been published to quantifying the effects of various weather variables on crop growth and yield for the long term, while such studies are exceedingly rare over India. In spite of that, the present study is focused on investigating how variations in various weather variables is influencing crop growth and production over the Haryana State. This study is unique by means of analyzing long-term (1990-2020) spatial and temporal variation of various weather variables like maximum and minimum temperature, solar radiation, rainfall, wind speed and relative humidity with the crop growth indicators like normalized difference vegetation index (NDVI) and leaf area index (LAI) and crop yield on monthly and yearly basis for *rabi* season crop (wheat) and *kharif* season crop (rice). The linear regression analysis has been carried out among weather variables, crop growth indicators and crop production.

2. Data and methodology

2.1. *Study area*

The Haryana is most agricultural prominent state of India having the total area 44,212 km^2 (1.37% of the

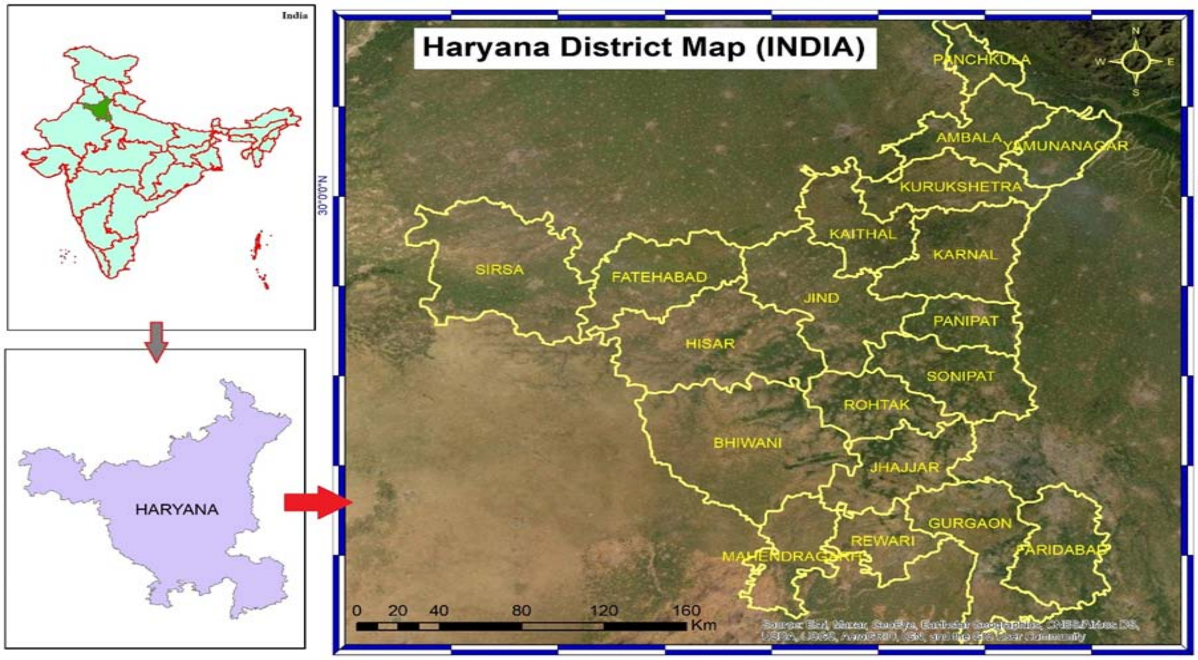

Fig. 1. Map showing the study area

nation's geographical area) and a population of over 2 crores (less than 2% of India's population). Haryana state is situated in the northwestern part (semi-arid and arid climate) of Indian region with geographic extent with latitudes from 27° 39' N to 30° 55' N, and longitudes from 74° 27' E to 77° 36' E, and with elevation ranges from 200 to 1200 feet above mean sea level. The annual precipitation occurring in the state ranges from 344 mm in Fatehabad to 1,108 mm in Yamunanagar districts with most prominent about eighty percent rainfall occurred during the monsoon season (June to September months) of every year. Primarily, it is agricultural state and mostly, crops are cultivated twice in a year, mainly rice and cotton in monsoon season and wheat in the post monsoon season (winter). Good quality and enough irrigation facilities with water sourced from canal and groundwater resources are also available in this state. The climatic condition of Haryana state is hot in the summer (April to June) average temperature (40°C) and cold in the winter (December to January) average temperature (21°C) with the pleasant months of spring in between throughout the year. Fig. 1 shows the geographical map of Haryana state. Surface water is supplied by the Sutlej through the Bhakra canal system and the Yamuna through the Western Yamuna Canal system.

2.2. *Data sets*

India Meteorological department (IMD) recorded the weather data at 6329 stations over the India have gridded and prepared from daily weather data at the National Data Centre, IMD, Pune, using Shepard method (Shepard, 1968). These datasets are prepared with a spatial resolution of 25km with one day interval time step. The long term (time period 1991-2020) daily gridded (0.25° × 0.25°) maximum and minimum temperatures and rainfall (0.50° × 0.50°) are downloaded from the Indian Meteorological department (IMD) over Haryana state. The other weather variables namely relative humidity (RH) and Wind speed (WS) are downloaded from the NASA's Prediction of Worldwide Energy Resources (NASA power) for similar time period (2010 to 2020) (https://power.larc.nasa.gov/data-access-viewer/).

2.3. *Description of vegetation indices*

The NDVI and LAI vegetation indices data derived from measurements made by the AVHRR sensor aboard NOAA polar orbiting satellite series (NOAA-7, 9, 11, 14, 16). The data is reprocessed to build consistent long-term records, enabling insight into changes in the Earth's environmental parameters, using knowledge collected through time about instrument performance and sensor properties. The NDVI data, in particular, give vegetation data to the global change and resource management communities for historical trend analysis and vegetation monitoring studies for land surfaces all over the world. Every half-month, the data are composites of daily values. This NOAA Climate Data Record file has a very high resolution of 0.05 degrees, globally. The NDVI CDR, like other operating CDRs, adheres to strict quality criteria set forth by the National Academy of Sciences and other expert groups to assist assure consistent and accurate results. (https://climatedataguide.ucar.edu/climate-data/ndvi-normalized-difference-vegetation-index-noaa-avhrr). The NDVI information is very useful vegetation indices to understand the vegetation growth and biomass. The NDVI is calculated by dividing the difference of near-infrared (NIR) and red (RED) reflectance values by the sum of near-infrared and red reflectance values. Wan *et al*, 2004 the small values of the NDVI indicates that the moisture stressed vegetation, while the higher values of the NDVI show the healthy and green vegetation. Mathematically, the NDVI index is computed as,

$$\mathrm{NDVI} = \frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{RED}}}{\rho_{\mathrm{NIR}} + \rho_{\mathrm{RED}}} \tag{1}$$

where ρ_{NIR} and ρ_{RED} are the land surface reflectance values in the 0.730–1.00 μm (infrared) and 0.55–0.70 μm (visible) regions of the electromagnetic spectrum, respectively.

The Climate Data Record (CDR) also having another vegetation indices datasets for the leaf area index (LAI) and fraction of absorbed photosynthetically active radiation (FAPAR) on a daily basis with the spatial resolution of 0.05°. These two biophysical variables useful for assessing vegetation stress, forecasting agricultural yields, and other modelling and resource management applications. Advanced Very High Resolution Radiometer (AVHRR) sensors derived LAI/FAPAR CDR provides the data from 1981 to the present (https://www.ncei.noaa.gov/products/climate-data-records/leaf-area-index-and-fapar). For the present study, the NDVI and LAI data from CDR has downloaded for the duration years 1991 to 2020.

2.4. *Description of yield data*

The Ministry of Agriculture's Directorate of Economics and Statistics has been recorded the nine fold land classification, irrigated area (source-wise and crop-wise) and total area under crops at district level over the India. The special Data Dissemination Standard Division, Directorate of Economics & Statistics, Ministry of Agriculture and Farmers Welfare, Govt. of India, New Delhi has published the data on web-based land use and statistics information system from the year 1997-98 for various crops (https://aps.dac.gov.in/LUS/Index.htm). The per hectare yield data of the *Rabi* season crop (wheat) and *Kharif* season crop (Rice) has been downloaded from years 1997-98 to 2017-18.

3. Methodology

The time series of the monthly and yearly vegetation indices (NDVI and LAI) and climate variables (Rainfall, maximum temperature, minimum temperature, relative humidity and wind speed) are constructed by averaging land-point grid values and spatial average values over the Haryana state. The temporal variations of vegetations indices and climate variables on monthly as well as yearly basis are observed to understand the basic character of the impact of climate on propagation characteristics of NDVI and LAI. The standard deviations are computed for monthly and yearly over the Haryana state to measure the variability of vegetation indices and climate variables. The correlation analysis is also carried out between vegetation indices and climate variables on monthly and yearly basis to understand the relationship between each vegetation indices with all the climate variables, separately. The Pearson correlation method is used for the computation of the correlation coefficients with the 5% significance level.

The Pearson correlation coefficients have been calculated between the vegetation indices and climate variables individually using Equation (2),

$$r_{xy} = \frac{\sum_{i=1}^{n} \left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right)}{\sqrt{\left(x_i - \bar{x}\right)^2 \left(y_i - \bar{y}\right)^2}} \tag{2}$$

Where, r_{xy} is the value of Pearson correlation coefficients between variables x (vegetation variable) and y (climate variable) with sample size n. The value of r_{xy} varies from -1 to +1. The index i represent the i^{th} month, and i^{th} year for the computation of correlation coefficients on monthly and yearly basis, respectively.

4. Result and discussions

4.1. *Temporal distribution of weather variables*

The present study has been done in three parts namely identification of the spatial pattern of mean weather variables for the duration year 1991-2020, temporal variation of weather variables on yearly and monthly basis for the duration year 1991-2020 and impact of the weather variables on crop growth variables and crop yield for wheat crop (*Rabi* season) and Rice crop (*Kharif* season). The linear regression approach is adopted for this study to examine climate change impacts on agricultural productivity in Haryana state India during the time period years 1991 to 2020.

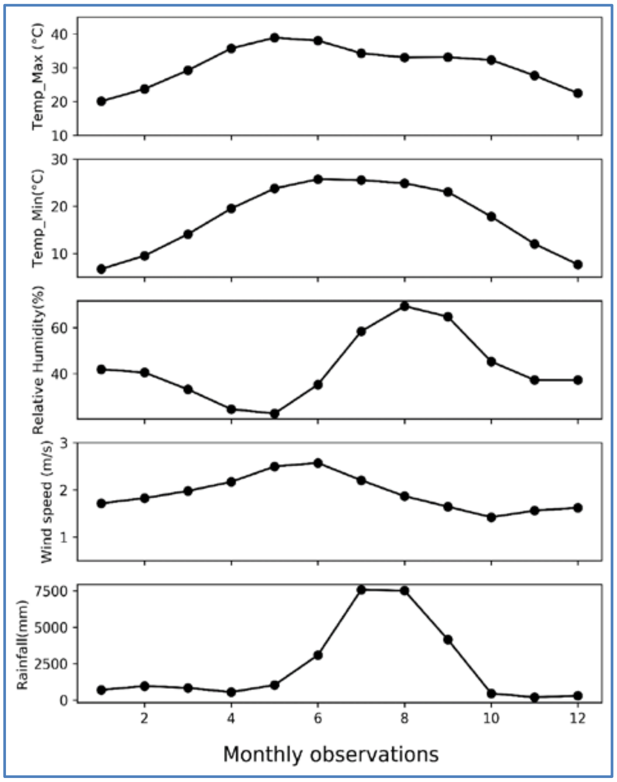

Fig. 2. Temporal variation of the various weather variables on monthly basis for the duration 1991-2020

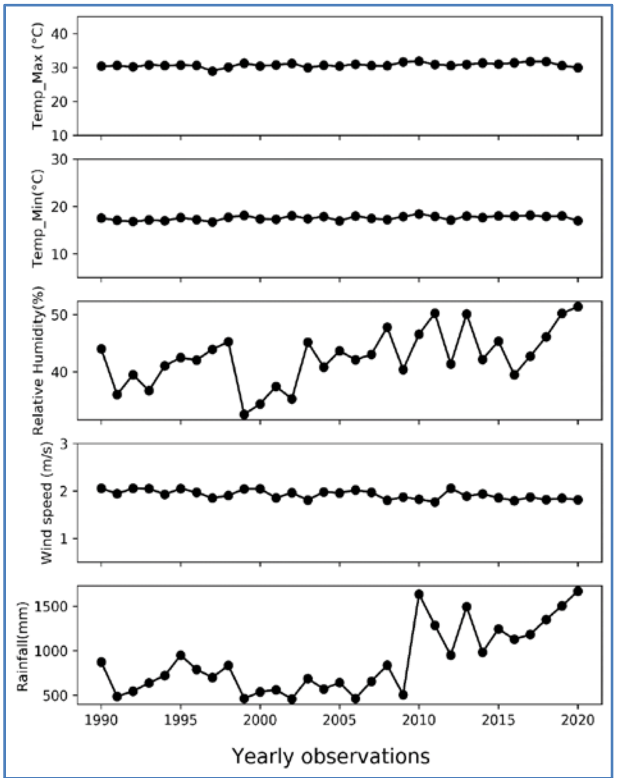

Fig. 3. Temporal variation of the various weather variables on yearly basis for the duration 1991-2020

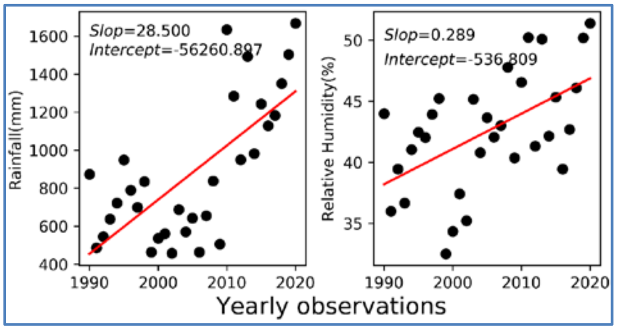

Fig. 4. Yearly changes in rainfall and relative humidity during the time period

Fig. 2 shows the temporal plots of the various weather variables namely maximum and minimum temperature, relative humidity, wind speed and rainfall on monthly basis. The monthly mean of all-weather variables except rainfall has taken for the duration 1991-2020 to study the temporal trend of the weather variables on monthly basis. In case of the rainfall, the total summation of rainfall has been carried out for every month for the duration years 1991-2020 on monthly basis. Fig. 3 shows the temporal plots of the various weather variables namely maximum and minimum temperature, relative humidity, wind speed and rainfall on yearly basis. The yearly mean of all-weather variables except rainfall (yearly summation of rainfall has been taken) has taken for the duration 1991-2020 to study the temporal trend of the weather variables on yearly basis. The temporal trend of minimum and maximum temperature is found approximately same with different magnitudes on monthly and yearly basis. The magnitude of the temperature is depending on the seasonal variability. The magnitude of temperature is found lower in winter season (January to February) due to cold weather and it showing the increasing trend up to the starting of monsoon season. During June to September months (monsoon season), the magnitude of minimum and maximum temperature is found almost constant but a very high increase in the magnitude of the rainfall and relative humidity is observed. The decreasing trend of the minimum and maximum temperature is observed during the October to December (post monsoon season) months and other weather variables like relative humidity and rainfall is also decreased. The mean of minimum and maximum temperature on yearly basis for the duration year 1991-2020 have shown approximately constant variation. There is no noticeable increase in temperature is observed for the time period year 1991 to 2020 over Haryana state. More specifically, a noticeable yearly variation is observed in rainfall and relative humidity over Haryana. Fig. 4 shows the yearly sensitivity of the rainfall (increases 28.500 mm per year) and relative humidity (increases 0.289 % per year). The rainfall and relative humidity are more important weather variable to simulate the crop growth and enhance the soil health.

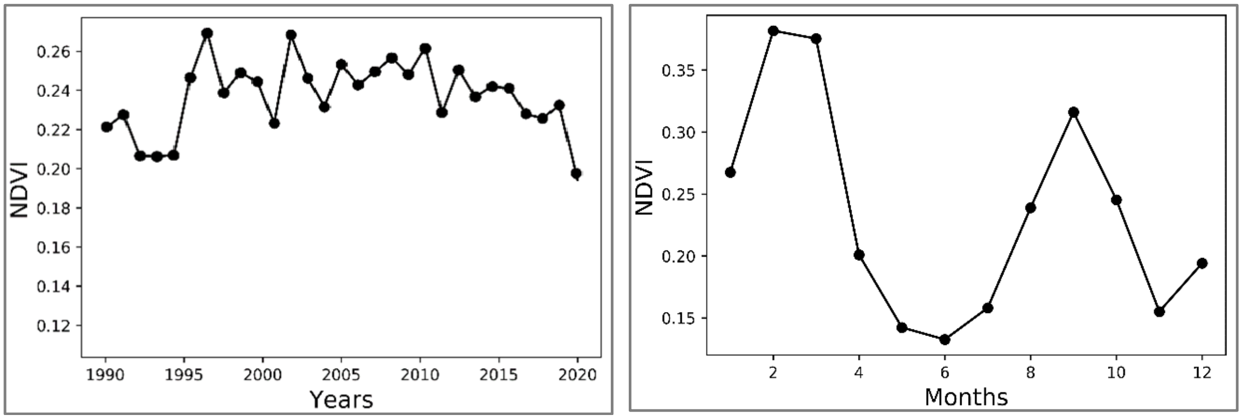

Fig. 5. Temporal variation of the normalized difference vegetation index (NDVI) on yearly and monthly basis for the duration 1991-2020

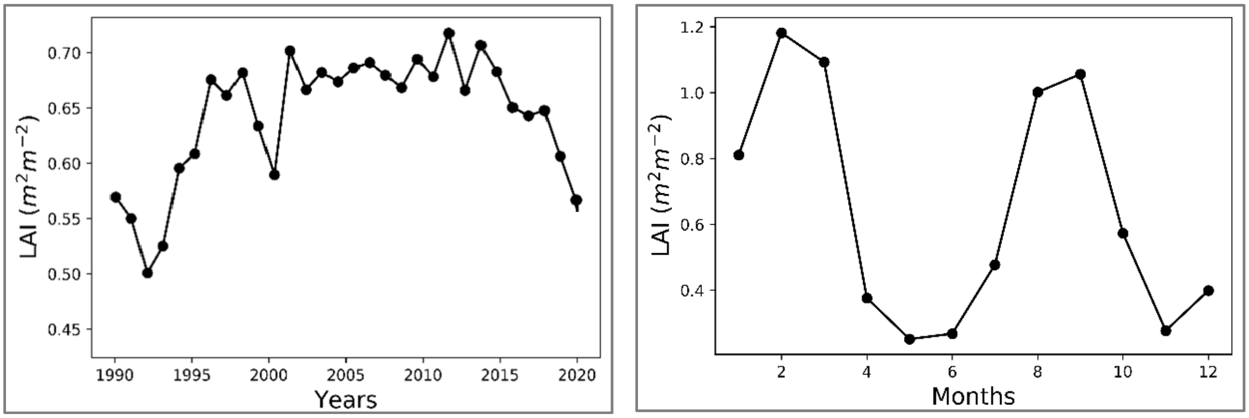

Fig. 6. Temporal variation of the leaf area index (LAI) on yearly and monthly basis for the duration 1991-2020

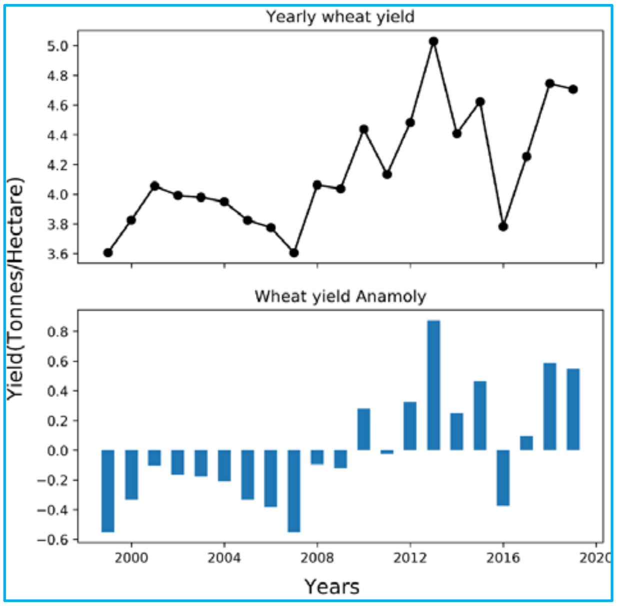

Fig. 7. Temporal trend of annual per hectare wheat crop yield along with the crop yield anomaly during the years 1998-2018 over Haryana

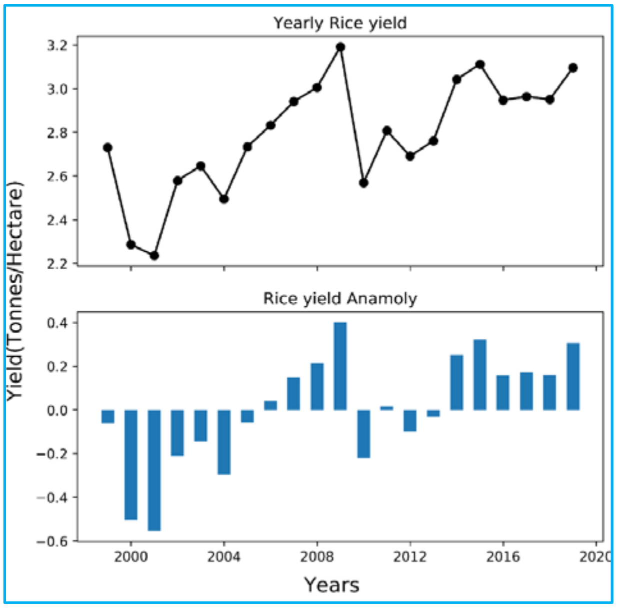

Fig. 8. Temporal trend of annual per hectare rice crop yield along with the crop yield anomaly during the years 1998-2018 over Haryana

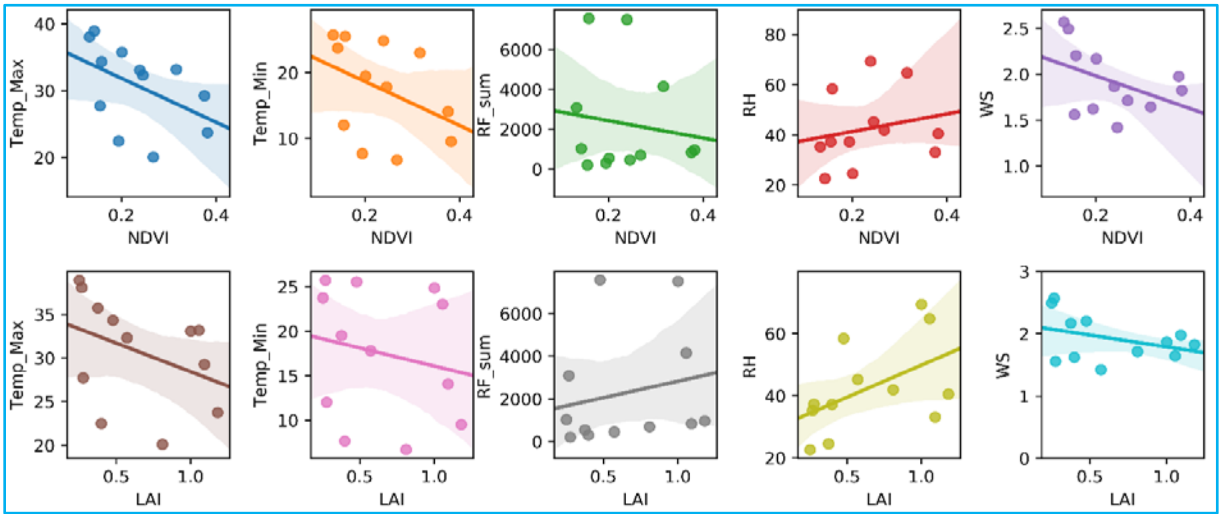

Fig. 9. Linear regression plots among weather variables and crop growth variables (NDVI and LAI) on average monthly basis during 1990-2020

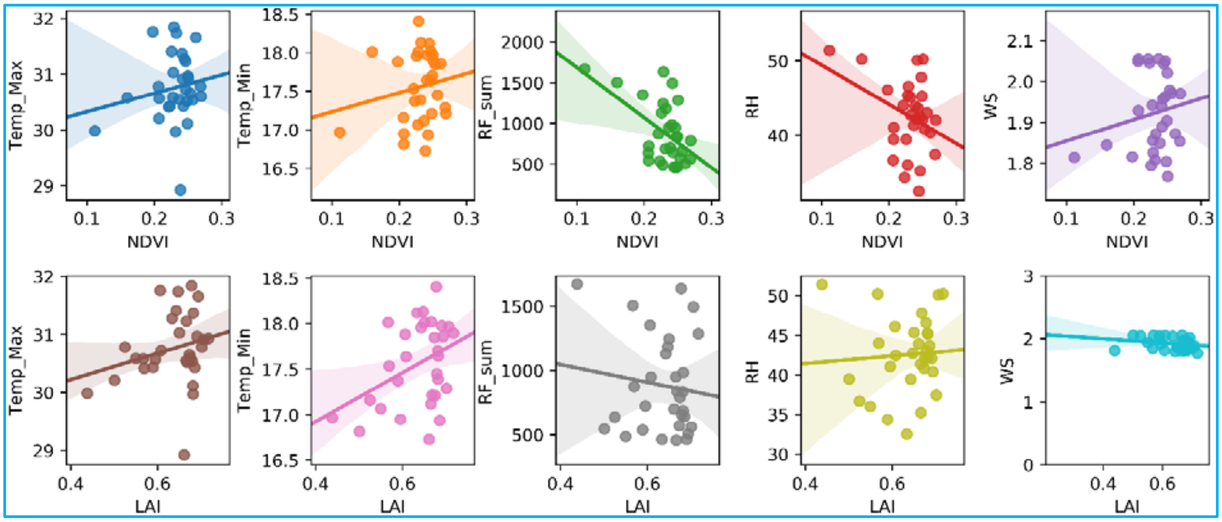

Fig. 10. Linear regression plots among weather variables and crop growth variables (NDVI and LAI) on average yearly basis during 1990-2020

4.2. *Temporal distribution of NDVI and LAI*

The monthly and yearly dynamics of weather variables linked with vegetation cover over the region. The NOAA-AVHRR sensors derived worldwide vegetation products allow for global as well as regional vegetation monitoring at various geographical and temporal resolutions (Ma and Veroustraete, 2006).

Figs. 5 and 6 shows the temporal variation of the crop growth variables namely normalized difference vegetation indices and leaf area index on monthly and yearly basis for the duration year 1991 to 2020 over Haryana. The lowest NDVI and LAI value is found just after the start of the hot pre-monsoon season (March-May). In the month of June, the NDVI and LAI begin to rise as the monsoon season (June-September) approaches the country. The rise in NDVI and LAI has continued since the commencement of the post-monsoon season, also known as the north east monsoon (October-December), which provides rain to portions of the country. The development of vegetation resulting the increase in NDVI and LAI due to a good amount of water received from the rain in the duration start of the summer monsoon to the winter monsoon month of October (Revadekar *et al*., 2012).

4.3. *Temporal distribution of crop yield on yearly basis*

Figs. 7 & 8 shows the temporal trend of the wheat & rice crop per hectare annual yield along with the crop

TABLE 1

Pearson correlation coefficients among weather variables, crop growth variables and crop yield

	Minimum temperature	Maximum temperature	Relative humidity	Wind speed	Rainfall
Monthly basis					
NDVI	-0.47**	-0.40*	0.21	-0.42*	-0.14
LAI	-0.38*	-0.20	0.50**	-0.37*	0.20
Yearly basis					
NDVI	0.17	0.17	-0.35*	0.18	-0.52**
LAI	0.25	0.39*	0.07	-0.23	-0.12
Rice Yield (*Kharif*)	0.21	0.21	0.50**	-0.17	0.45**
Wheat Yield (*Kharif*)	0.26	-0.18	0.19	-0.17	0.17

*5% significant **1% significant

anomaly during the year 1998 to 2018. The annual per hectare wheat yield show the regularly increasing trend from the year 2007 to year 2018 in comparison to the temporal crop yield anomaly plot also indicated that the annual per hectare wheat production has increased after the year of 2010 from the mean wheat crop yield during the years 1998 to 2018 except two years 2011 and 2016. While, the remaining previous years from 1998 to 2009, the wheat crop production lower was obtained from the average per hectare wheat crop yield during the years 1998 to 2018 (Fig. 7).

The annual per hectare rice yield show the regularly increasing trend from the year 2001 to year 2018 in comparison to the previous years from year 1998 to year 2000 except few years in between. The temporal rice crop yield anomaly plot also indicated that the annual per hectare rice production has increased after the year of 2006 from the mean rice crop yield during the years 1998 to 2018 except four years in between 2010, 2011, 2012 and 2016. While, the remaining previous years from 1998 to 2005, lower the rice crop production was obtained from the average per hectare rice crop yield during the years 1998 to 2018 (Fig. 8).

4.4. *Impact of weather variables on the crop growth variables (NDVI and LAI)*

The assessment of weather variables on the crop growth variables are observed on the linear regression analysis among various weather variables and crop growth variables. Figs. 9 and 10 show the scatter plot among various weather variables (minimum temperature, maximum temperature, rainfall, relative humidity and wind speed), NDVI and LAI monthly and yearly basis during the time period years 1991 to 2020, respectively.

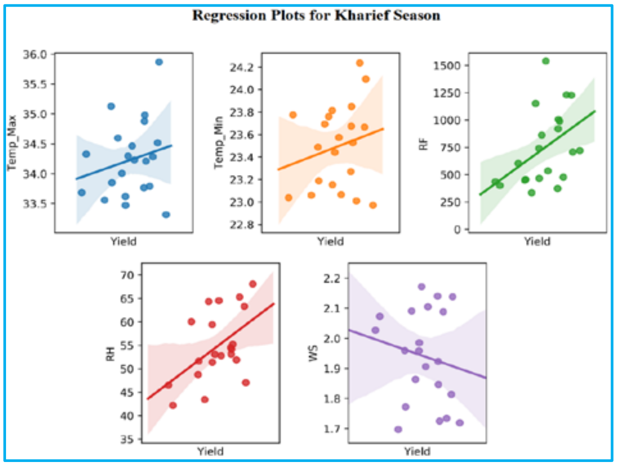

Fig. 11. Scatter plots among weather variables and rice crop yield (*Kharif* season) on average yearly basis during 1998-2018

Table 1 shows the values of Pearson correlation coefficients among the various weather variables, crop growth variables (NDVI and LAI) and crop yield on monthly and yearly basis. The value of Pearson correlation coefficient is found among various weather variables (minimum temperature, maximum temperature, relative humidity, wind speed and rainfall) and NDVI -0.466, -0.402, 0.207, -0.424, and -0.139 on monthly basis, respectively (Koyel Sur *et al.*, 2018). However, on yearly basis, 0.169, 0.171, -0.345, 0.175 and -0.521, respectively. The value of Pearson correlation coefficient is found among various weather variables (minimum temperature, maximum temperature, relative humidity, wind speed and rainfall) and LAI -0.383, -0.201, 0.501, -0.368 and 0.202 on monthly basis, respectively. However, on yearly basis, 0.247, 0.392, 0.067, -0.233 and -0.123, respectively (Wedyan *et al.*, 2022), Bhavsar, P.N. and Patel, J. N. (2016).

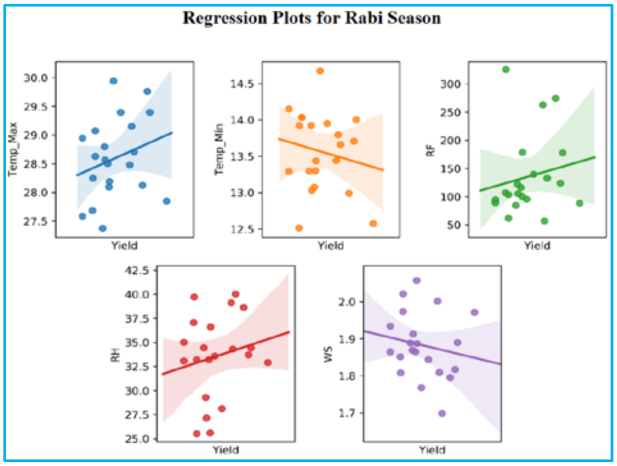

Fig. 12. Scatter plots among weather variables and wheat crop yield (*Rabi* season) on average yearly basis during 1998-2018

4.5. *Impact of weather variables on the crop yield*

Figs. 11 and 12 show the scatter plots among various weather variables and crop yield (rice and wheat) during the years 1998 to 2018. The value of Pearson correlation coefficient is found among various weather variables (minimum temperature, maximum temperature, relative humidity, wind speed and rainfall) and rice yield is 0.214, 0.214, 0.502, -0.170 and 0.446, respectively. However, for the wheat crop yield, 0.260, -0.177, 0.185, -0.172 and 0.169, respectively. The highest and positive impact of the relative humidity and rainfall weather variable is found on the rice crop production according to the obtained Pearson correlation coefficients results in this study in Haryana State of India. The minimum and maximum temperature is also supporting the rice production. However, the wind speed showed the negative impact on the rice production. In India, the rice crop is growing during the monsoon season, a heavily rainfall is occurred and the mean temperature almost remains optimum for the rice crop.

The minimum temperature supports the wheat crop production, while the maximum temperature showed the negative correlation with the wheat yield. The positive impact of rainfall and relative humidity is found on the wheat crop production, while the wind speed is showed the negative impact on the wheat crop production. In all scenarios, the effect of increased temperature on wheat output was negative, while rainfall had no significant influence on wheat yield. Wheat yield tends to decrease by 7% for each degree increase in mean temperature over India. (Sonkar *et al.*, 2019). This appears to be catastrophic, as recent climate projections over India predict that the surface temperature would climb above 5 degrees Celsius by the twenty-first century (Basha *et al.*, 2017). Overall, this study has found the annual increase in wheat crop yields approximately 0.044 tons per hectare, and rice crop yield 0.029 tons per hectare.

5. Conclusions

This investigation provides a general insight into the role of long term weather variability impact on NDVI and LAI on monthly and yearly basis time scale over the Indian state of Haryana during the time period of years 1991 to 2020 along with the crop yield. The results of the investigation revealed that certain meteorological conditions are conducive for NDVI and LAI rises. The values of NDVI and LAI reach their maximum twice a year, due to the two crop growing seasons that occur in Haryana, *Rabi* and *Kharif* season. The annual rainfall and relative humidity is increases with 28.5 mm per year and 0.289 % per year, respectively. In case of crop yield, the value of Pearson correlation coefficient is found among various weather variables (minimum temperature, maximum temperature, relative humidity, wind speed and rainfall), rice yield (0.214, 0.214, 0.502, -0.170 and 0.446) and wheat yield (0.260, -0.177, 0.185, -0.172 and 0.169), respectively. The highest and positive impact of the minimum and maximum temperature, relative humidity and rainfall weather variable is found on the rice crop production in Haryana, while the wind speed showed the negative impact on the rice production. The minimum temperature, rainfall and relative humidity supports the wheat crop production, while the maximum temperature and wind speed showed the negative correlation with the wheat yield in Haryana during the time period years 1998-2018. Overall, this study has found the annual increase in wheat crop yields approximately 0.044 tons per hectare, and rice crop yield 0.029 tons per hectare.

Disclaimer : The contents and views expressed in this study are the views of the authors and do not necessarily reflect the views of the organizations they belong to.

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