

# **Monitoring Vegetation Health through Spatio-Temporal Techniques and indices from 2009 to 2019: A Case Study of District Jhang**

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## **ABSTRACT**

Plants' health status is a great concern for agricultural research due to vast environmental losses and gains that are causing changes in vegetation coverage. Organizations all over the world play a significant role in plant health management. This study will highlight the plants' health status of the Jhang district and will be able to recognize the factors that affect the physical condition of the plants while determining the changes in plants' health over period of ten years' (2009 -2019). Advanced integrated spatial technologies such as GIS and RS have been used in monitoring health status of plants. Geographical factors including (temperature, soil adjustment, and plant cover) with respect to their spatial analysis (NDVI, SAVI and LST) were performed respectively. NDVI values showed energetic changes with mean values ranging from 0.0518in (2009) to 0.1944 in (2019). The NDVI outcome indicated that the plants had great concentrations at the central part in 2009 (0.5209) while showing increased concentration towards the Southern and Northern part in 2019(0.5467) while lowest vegetation cover (-0.3340) was found in the western part of Jhang district. The results for SAVI 2009, 2014 and 2019 were 0.07791, 0.8705 and 0.9268 respectively. The results revealed that suitable soil was present all along the study area except the western side where dry soil was found which is not suitable for plant growth. LST values for 2009 to 2019 were 41.0300 & 47.5718 respectively. The secondary data regarding the forest cover was obtained from the Department of Forestry. It is concluded from results that the variation in temperature, soil and vegetation cover in different parts of Jhang District is what accounts for the significant differences in plant health. It is proposed that the method applied in the researched region may also aid in assessing the health condition of vegetation. Although the area researched is limited, this method would be highly effective if utilized in a broader region.

**KEYWORDS:** Environmental, NDVI, Temperature, Variation, Vegetation

## **1. INTRODUCTION**

Plant Biomass has played a key significant role in human life being a multifunctional resource (Folega et al., 2023) .In modern era, determining plant health is major task done by remote sensing and GIS (Chaudhary et al., 2022). Plant health status is a vital component of crop production. They are a primary source of nutrition for livestock as they contribute 80% of the food

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consumed by animals and humans (Rizzo et al., 2021). Systems for imaging crop health are vital for enhancing the conditions of plant growth by gathering biologically pertinent information (Zeidler et al., 2019). The role of optical technologies are used as practical tools observing health of plant with help of spectral signatures (Liew et al., 2008). Spectral imaging plays a vital role in high throughput phenotyping, encompassing a wide range of natural bounds. The Normalized Difference Vegetation Index (NDVI) utilizes exact wavelengths evaluate to crop health and performance (Stamford et al., 2023). It is one of the most important and easiest method to assess vegetation and plant growth (Döring et al., 2012). To extract the information about the vegetation cover, several spectral vegetation indices are used that are basically derived from the remote sense data for examining the physical and the biological characteristics of plants. To understand the surface energy balance along with its physical and chemical properties LST tends to be a significant parameter in determining the surface matter exchange and is widely used in Hydrology, geo chemistry, biology and in soil studies. LST basically procedures the temperature of the surface. Region such as central Africa, where the vegetation is high tend to retain LST due to high ratio of absorption of plants particularly due to low albedo. While contrarily the desert areas where there is limited vegetation, the absorption is lower (higher albedo) thus causing increase in the LST (Aliyu et al., 2022).

In a study conducted in Morocco, remote sensing metrics were utilized to assess agricultural drought and simulate vegetation health over the time frame of (1984-2016). The findings indicated that 7% of crop yields were healthy during (2010-2016), in contrast to 50% during (1984-2000) (Hakam et al., 2023). In all the agro ecosystems, the microorganisms act as a key indicators and active agents in nutrients sequestration. They are the natural habitats of all the soil processes (Sahu et al., 2019). Various biotic and abiotic stresses are a critical threat to crop productivity (Lee et al., 2021).

In direction to realize the Sustainable Development goal with reference to Climate change in Sub Sahara Africa, it is the major practice to assess the vegetation health in ecosystems along with major agro systems (Folega et al., 2023). The methodology of their research involves an NDVI imaging system based on Raspberry, utilizing easily accessible components and robust multi-reference calibration protocols to ensure accurate NDVI measurements. Despite its lower cost, the system yields comparable NDVI values when compared to a commercial system (Mishra et al., 2019). Plant health is a widely used term, yet its definition remains unclear. We can explore various concepts of plant health and establish a framework to categorize them based on their stance in different philosophical debates. We also examine how these perspectives relate to mainstream and

alternative approaches to plant protection and propose methods to reconcile conflicting viewpoints. It is important to acknowledge that none of these perspectives is without contradictions. Rather than providing a new definition of plant health, our objective is to create a conceptual framework that guides discussions on plant health issues and facilitates organized debates (Döring et al., 2012).

## 2. MATERIALS AND METHODS

### 2.1. Study area

Jhang is a District of the Punjab province and occupies the central region of Pakistan. It covers an area of 6357 Sq.km and located in East bank of River Chenab. The geographical coordinates are 33 ° 40 '31" in "North and 72 ° 41 '48" in East. The two major rivers, Chenab and Jhelum flow into Jhang District and converge at the Trimmer. The Climate of this area is hot and humid in summer seasons while dry in winter. The weather remains warm and humid for nine months, except in June where maximum temperature rises to 46 °C.

This region is characterized by two rivers, which results in well drained, highly productive soil, but only in the vicinity of the riverbanks. It encompasses a small wooded area adjacent to the forest floor and includes (Caprasphella), Fresh (Tamarixphela), Mesquite (Prosopisandolaus), Jund (Prosopis scenario), Berry (Zezfusosmoritana), Van (Salvadoruloides), Ceres (Albiziliciba c), Dalbergiasissoo, and Eucalyptus (E-Comadulensis) etc (Shoaib et al., 2023).

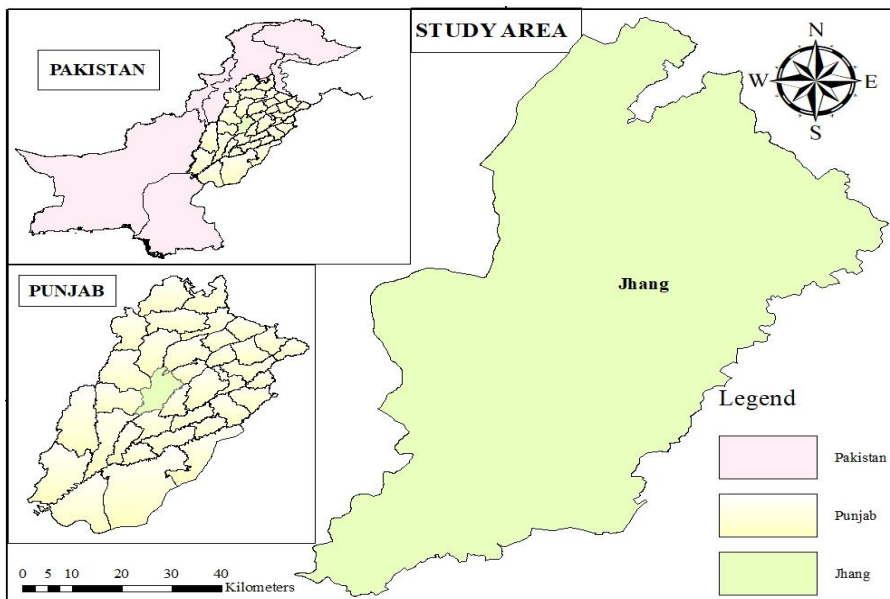


Figure 1: Showing study Area

## 2.2. Data collection

The vegetation indices were gathered through Landsat OLI and TIRS data for year (2009-2019) sourced from the United States Geological Survey (USGS) portal (<http://www.earthexplorer>). The characteristics of the datasets are detailed in Table 1 below. Furthermore, secondary data was obtained from the Forest Department of Jhang District to gather the information about the plant health. In response to the demand for enhanced techniques to evaluate the wellbeing of forest ecosystems, the Forest Department of the government established a program for monitoring forest health as part of its Environmental Monitoring and Evaluation initiative. The program commenced in 2009 and by 2019 it was active in critical regions of Jhang District, Punjab. This objective outlines an overview of the program, the indicators and methodologies developed, and a summary of findings after four years of observation and research.

**Table 1:** Description about the wavelengths of Landsat 8 Bands

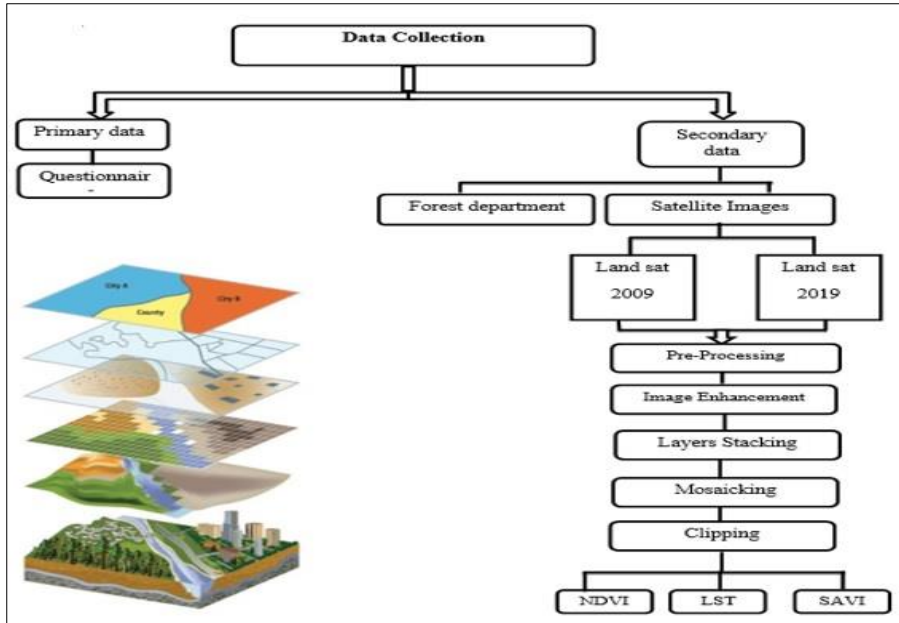
<b>Bands</b>	<b>Description</b>	<b>Wavelength[um]</b>	<b>Resolution[m]</b>
<b>1</b>	Coastal aerosol	0.43 - 0.45	30
<b>2</b>	Blue	0.45 - 0.51	30
<b>3</b>	Green	0.53 - 0.59	30
<b>4</b>	Red	0.64 - 0.67	30
<b>5</b>	Near Infrared	0.85 - 0.88	30
<b>6</b>	SWIR 1	1.57 - 1.65	30
<b>7</b>	SWIR	2.13 - 2.29	30
<b>8</b>	Panchromatic	0.50 - 0.68	15
<b>9</b>	Circus	1.36 - 1.38	30
<b>10</b>	Thermal Infrared1	10.60 - 11.19	100
<b>11</b>	Thermal Infrared2	11.50 - 12.51	100

**Source:** Description and Quality of Satellite Data

## 2.3. Normalized Difference Vegetation Indices (NDVI)

The Normalized Vegetation Index (NDVI) of the study area was calculated with the help of ArcGIS10.5 to calculate the registered display rate near the red and the near- infrared invisible (NIR) limits. The Different Vegetation Index (NDVI) is a measure of "green" vegetation or photosynthesis and is one of the most widely used indicators (Siddiqui & Javid, 2018).

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



**Figure 2:** Workflow diagram of the study

## 2.4. Soil Adjusted Vegetation index (SAVI)

Soil Adjusted Vegetation Index (SAVI) is a kind of vegetation index that varies depending on soil type and soil texture (Hu et al., 2021). The index is a transition course that reduces soil light irradiance from the visible vegetation index are includes the long red and the near infrared (NIR) distances (Siddiqui & Javid, 2018). Given as an indication. The index is given

$$SAVI = \frac{(1+L)(NIR - RED)}{NIR + RED + L}$$

## 2.5. Land Surface Temperature (LST)

Land surface temperature (LST) is the amount of radiation emitted by the sun's rays. In this study area, LST helps capture the temperature between 2009 and 2019. The LST metrics were derived from reflective data in the bands of the trio of Landsat that were transformed into the temperature of the surface readings. The LST values were calculated using reflective values in the radios of the three Land sat images that were converted to the temperature of the reading surface. The method reliefs to obtain the existing temperature of a place (Aliyu et al., 2022).

## 2.6. Boolean method in comparative analysis

This section describes the elemental features of the Boolean approach in approximate analysis and also describes the process of using the Boolean comparison (Ibrahim et al., 2021). They're easy to understand because they correspond to logical principles that are common to multiple types of

exploration in social knowledge, especially case studies (Yin, 1984). Grounded on some studies conducted, including the development of proposition and the construction of a quality database, the path taken in the Boolean approximate analysis is as follows (Romme, 1994; Ragin, 1987).

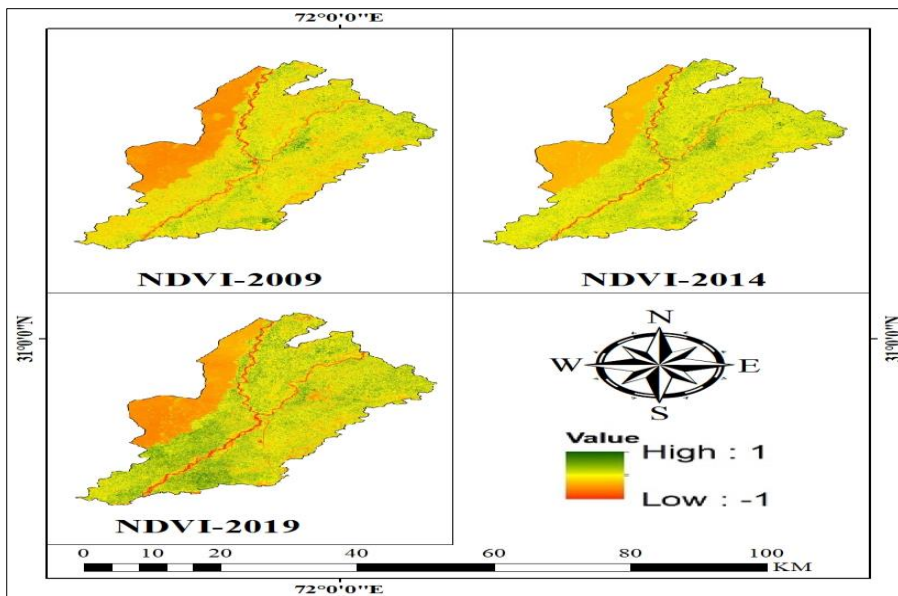
### 3. RESULTS AND DISCUSSION

Results of Correlation Analysis of Normalized Difference Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), Land Surface Temperature (LST) and Boolean NDVI Method for Determining Health vegetation in the area are as follows in Table2, 3 and 4 respectively.

#### 3.1. Normalized Difference Vegetation Index (NDVI)

**Table 2:** Showing statistical results of NDVI

Satellite Image Year	Minimum Value	Maximum Value	Mean	Standard Deviation
2009	-0.9813	0.5209	0.0518	0.0869
2014	-0.2227	0.5803	0.1476	0.0864
2019	-0.1618	0.5467	0.1944	0.0987



**Figure 3:** NDVI in study area (2009, 2014 &2019)

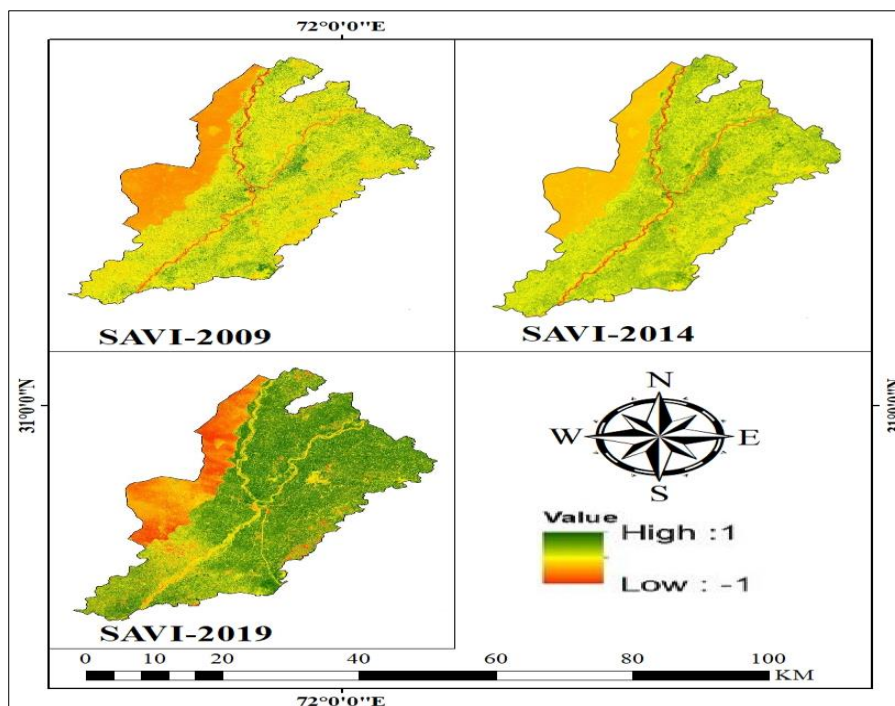
NDVI results revealed the energetic changes from 2009 to 2014 with mean values ranging from 0.0518 to 0.1944. The maximum values of NDVI ranged (0.5209) in 2009, (0.5808) in 2014 and (0.5467) in 2019. In the last 10 years, the value of vegetation has increased due to flooding. The results reveal that there is still growth and healthy vegetation in the study area particularly in the southern and central part while the minimum values (-0.1618) were

found along the western side. The flood waves of 2010 and 2014 play important role to increase vegetation in the 2019. Similar findings of research were gathered by (Hussain et al., 2023) which aimed to study the land cover in relative with changed vegetation index with help of multi progressive spatial data in Sahiwal Region, Pakistan. Plants grow abundantly near streams and banks. The results are in line with the findings gathered by (Eswar et al., 2016) which aimed to study the relation between LST with changed vegetation indices. The Purpose of this research was to compare the results of five different VIs, namely NDVI, FVC, the normalized difference water index (NDWI), soil adjusted vegetation index (SAVI), and modified soil adjusted vegetation index (MSAVI), for thermal sharpening using the Dastard thermal sharpening model over agricultural and natural landscapes in India.

### 3.2. Soil Adjusted Vegetarian Index (SAVI)

**Table 3:** Statistical Results of SAVI

Image Year	Minimum Value	Maximum Value	Mean	Standard Deviation
2009	-0.9465	0.7791	0.0774	0.1300
2014	-0.3340	0.8705	0.2214	0.1297
2019	0	0.9268	0.7309	0.0724



**Figure 4:** SAVI in study area (2009, 2014 &2019)

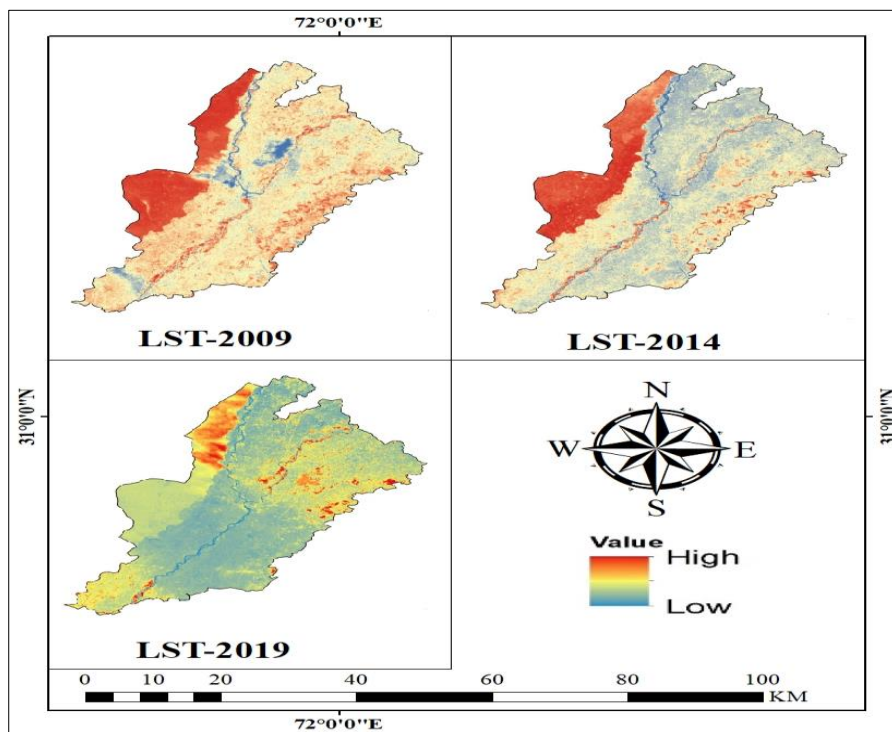
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The maximum values of SAVI observed in figure 3 received for the year 2009, 2014 and 2019 were 0.0774, 0.8705 and 0.9268 respectively. The results gathered reveal good increase in vegetation due to soil runoff mainly after floods in (2019) which aids in plant growth. The results reveal that healthy and rich soil promotes healthy vegetation in Northern, central and southern part of the study area while the western part remains infertile and unhealthy for plant growth.

### 3.3. Land surface temperature (LST)

**Table 4:** Statistical results of LST

Satellite Image Year	Minimum Value	Maximum Value	Mean	Standard Deviation
2009	19.6789	43.0300	36.9591	4.2699
2014	24.2469	45.1163	37.3942	4.4989
2019	25.6953	47.5718	38.8725	5.3698



**Figure 5:** LST in study area (2009, 2014 &2019)

The LST maximum values with reference to figure 4 for year 2009, 2014 and 2019 were observed 43.0300, 45.1163 and 47.5718 indicating hot regions. High temperature was recorded along the western region of Jhang district particularly resulting in arid region, thus resulting in no vegetation. At the same time the lowest value of LST was observed 19.6789 in (2009) near

water bodies (Chenab and Jhelum). The maximum value of LST decreased in 2019 in the western part particularly after the floods. The mean LST values from (2009 to 2019) show dynamic change in temperature from 36.9591 to 38.8725. Over the last 10 years, the values show us a good reduction in temperature due to flooding and vegetation. These results are in line with the findings from the study (AŞIK, 2020). Which uncovered a favorable connection between LST and NDVI (0.82 and 0.95) for the years 2015 and 2016 respectively, whereas the respective values for the LST and SAVI correlation were 0.87 and 0.87 this research indicates that satellite data and the vegetation indices derived from it can assist in observing agricultural drought.

### 3.4. Boolean method in comparative analysis of NDVI, SAVI & LST

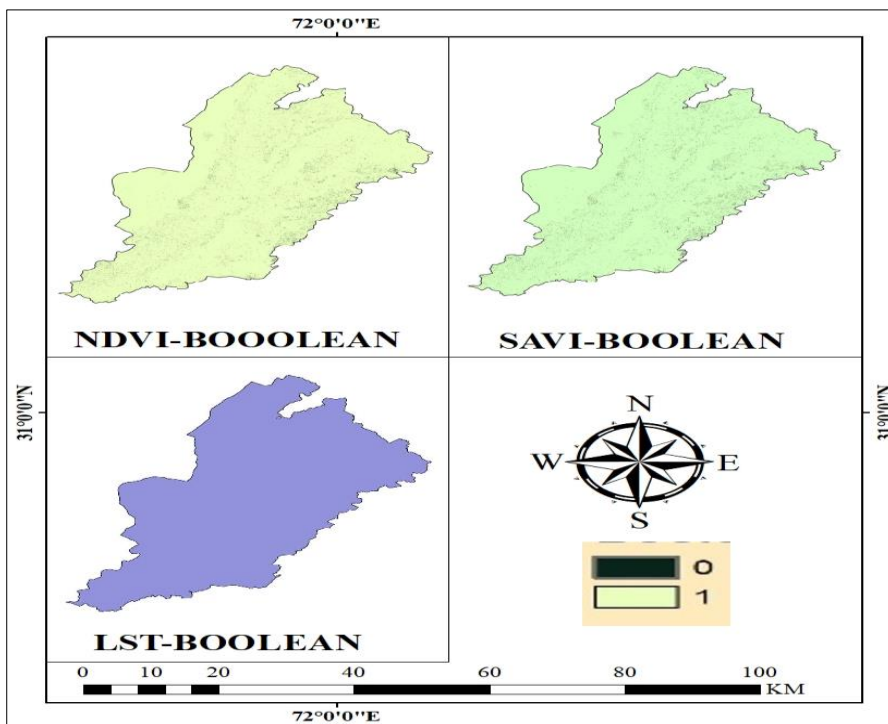
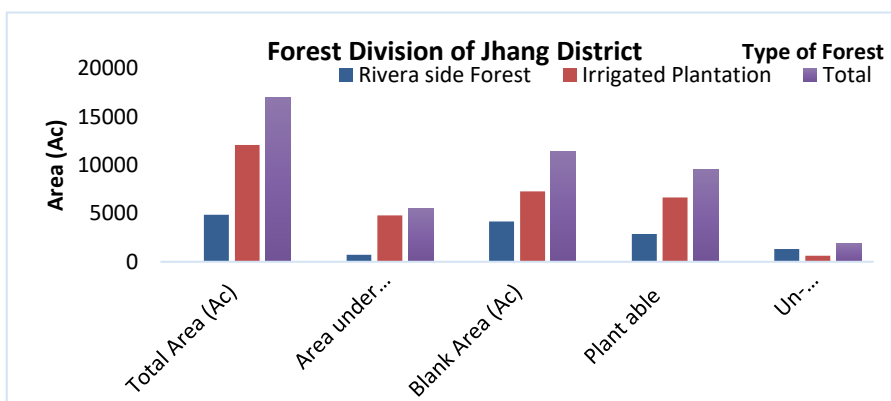


Figure 6: Boolean analysis of NDVI (2009, 2014 & 2019)

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According to the above data, overall correlation between 2009, 2014 and 2019, the results shows that there is an invisible increase of vegetation in Jhang district particularly in south, North and central region. Aggregate data showed a result of 0 (117281) points with black coloured soil indicating infertile soil. Also, point 1(6747682) indicates a light green colour result indicating rich soil. Finally, the results show that fertile soils cover more area than barren lands in Jhang district. Similar analysis of research was carried by (Hussain et al., 2023). In Sahiwal region, the average, NDVI and SAVI values were noted as 0.19 and 0.65 respectively.



**Figure 7:** Total forest area of Jhang (Data gathered from Forest Department)

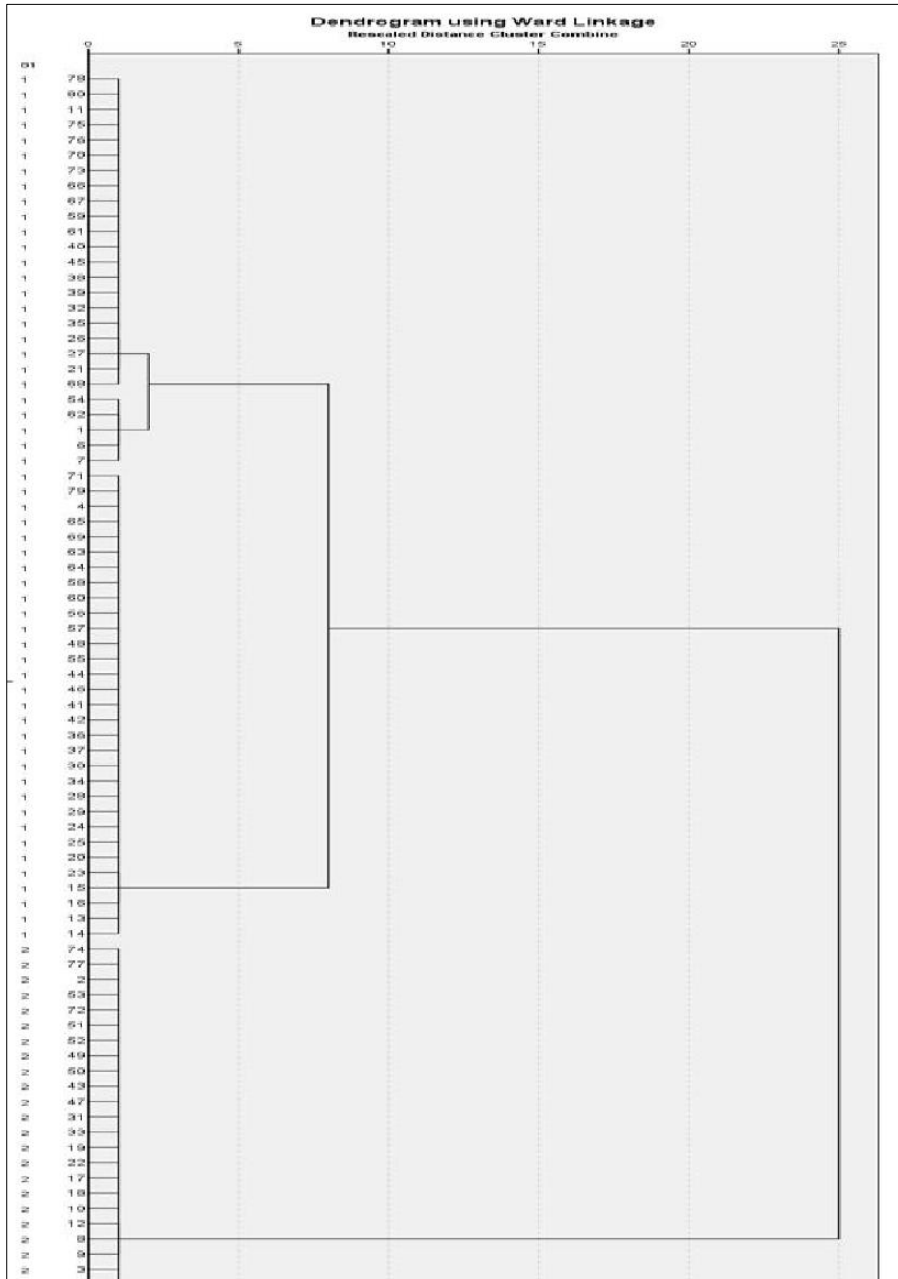
The above data provide details of the complete tree cover in Jhang district. The forest is divided into two types, the first is the natural growth forest and the second is the irrigated forest area. The total forest area covers 16977 (59%) hectares out of which 5564 hectares is under (23%) forests and 11450 acres is (10%) bare land and 9529 acres is bare land, and 1921 acres is out of forest control.

### 3.5. Cluster Analysis

To determine the general information about the relation of plant health data and its processing Cluster analysis was used to avoid the outliers present in the research. The main purpose of adopting this analysis was to assure the division of data on the basis of their similar characteristics (Mohammadi & Prasanna, 2003). Result gathered by cluster analysis revealed significant statistics of 0.828 highlighting the increase in total plants growth in last ten years and their significant effects in relation with soil and temperature. Similar analysis was performed by (Jasiński, 2021) in which non hierarchal approach was adopted with k means algorithm to find the outlier's. In this study area, a combination of classifications is used to show that the main data, soil, and temperature are changeable, and the number of plants increased at the end of the decade. The WARDS approach is used for outcomes and grades range from -1 to 1.

**Table 5:** Reliability Statistics

Cronbach's Alpha	Number of Items
.828	2



**Figure 8:** Dendrogram representing Cluster analysis Response

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An attempt was made in the overhead research to show the complete capacity of plants growing in the study area by statistically significant means for group analysis indicating individual effects of soil and temperature. The result obtained by cluster analysis between the reliable estimates of complete stores grown in a decade and soil and temperature equipment is positive 0.828 with the closest crop and plant size in the study area.

Cluster analysis with Ward's method classified all the data into 4 major clusters as shown in Fig 8 above. For group analysis, significant means showing the statistical significance of soil and temperature variables were tried to express the total number of plants growing in Jhang in the above question. Effects of result in group analysis between total plants grown at end of decade and individual effects of soil and temperature. There are three groups from which different sources appear. In group 1 you cross 6 answers, in group 2 you skip 34 answers and in group 3 you skip 25 answers.

#### **4. CONCLUSION**

The results of this study demonstrate the following major findings of plant health conditions in Jhang district from 2009 to 2019 using RS and GIS strategies. The maximum NDVI values (0.5803) and (0.5467) were found in year 2014 and 2019 respectively. The results revealed progressive vegetation growth after the floods particularly in the central region in 2014 along the two major rivers (Chenab and Jhelum) which further increased towards the Southern and Northern part in 2019 after the tree plantation campaign by the government of Jhang district. On contrary, the western part of Jhang district revealed negative values of NDVI (-0.9813) showing no vegetation. Secondly, the SAVI approach highlighted the soil fertility assess plant health status. The results for maximum values of SAVI for year (2009, 2014 and 2019) were 0.07791, 0.8705 and 0.9268 respectively. The results of SAVI revealed that soil fertility was present all along the central, northern and southern part while the western part was arid with less fertile soil. Determining environmental factors including high temperature, rainfall and relative humidity through LST for year 2009, 2014 and 2019 observed highest value in 2009 (63.0300) along western region while temperature decreased in 2019 (47.5718) due to plantation of tress. While Correlating all the three indices (NDVI, SAVI and LST), it can be evaluated that in 2009, due to increase in LST, the maximum value of SAVI and NDVI declined highlighting less vegetation in district but in 2014 after the floods along the riverine bed of Chenab & Jhelum and in 2009 after the initiative of government for tree plantation, the LST values declined showing massive sharp increase in NDVI and SAVI determining increase in vegetation all along study area except the western part. Our investigation's outcomes align with the work of Alademomi et al. (202

0), who examined the correlation between LST, NDVI, and EVI in relation to land cover alterations during the dry season. Meanwhile, Tariq et al. (2020) explored the connection between LST and land cover metrics, revealing that vegetation can significantly influence Land Surface Temperature (LST) by absorbing and reflecting solar radiation energy, as well as managing latent and sensible heat transfer (Yuan et al., 2017). Result gathered from the wards approach of cluster revealed the Reliability Statistics of 0.828 that is good and represents high density of vegetation in study area.

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