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CROP HEALTH MONITORING USING GEOSPATIAL TECHNOLOGIES FOR NASHIK DISTRICT, MAHARASHTRA

Vaishnavi Adhav[1], Sandipan Das[2], Vidya Patkar[3]

[1]Symbiosis Institute of Geoinformatics,
[2]Symbiosis International (Deemed University), Pune India
*Email: [3]drvidyapatkar@gmail.com

Abstract

Agriculture or farming is practiced for producing food grains, feed, fibers, and many more necessary products by cultivating various types of crops. Therefore, the agriculture sector majorly contributes to the economy of both developed and underdeveloped countries. Remote sensing and GIS (Geographic Information System) technologies have been effectively used for monitoring several annual Indian crops like rice, wheat, maize, etc. Hence, evolving an approach for monitoring many crop cultivations using these advanced technologies has turned out to be a necessity. Geospatial data which is acquired by unmanned aerial vehicles such as satellites or drones can be used to detect and identify the health of crops. Remotely sensed imageries are used as mapping tools to categorize crops, examine their health, mapping of soil characteristics, and monitoring farming practices. Areas which are highly or moderately affected by insects and pests can be easily identified by the geospatial technology to apply the precise fertilizer or pesticide to an affected area of crop cultivation. It helps to improve the productivity of the land as well as lessens environmental influences. Remotely sensed images can be taken not only to identify diseases and infestations but also to monitor healthy crop fields. the main objective of this project is to monitor and identify the health condition of crops, as well as, to analyse the changes in its health using geospatial data and techniques. These advanced technologies are implemented to fulfil the objectives of this project. Crop health identification and determination are done by using many vegetation indices such as NDVI, GNDVI, CVI, and DVI. Also, differences in the health condition of crops are determined. The health condition of the soil, temperature of the soil, and water balance has also taken into consideration.

Key words: Remote sensing, GIS, Crop health, Geospatial techniques, Agriculture

Introduction

Healthy food is depending on the health of crops. Crop health is very essential to the farmers for their healthy growing production. Monitoring the health condition of crops is important to maximize the crop yield as well as to gain profit for the farmers. The health of crops can get affected mainly because of the production of the wrong mixture, expensive yield production, organization of smallholder farmers, poor quality control at the processing level, weather changes, low soil fertility, and more significantly from pests and disease infestations. (Rishiraj Dutta, 2006) The health of soils is much important as it provides essential nutrients to crops. The fertility of the soil is reliant on various characteristics such as accessibility of water, soil moisture, various soil nutrients, soil pH, soil temperature, etc. Thus, the health of crops is relying on soil health as well as on cumulative rainfall and suitable temperatures. Therefore, it is necessary to notice a lack of moisture, low soil fertility, pests, fungal, and weed infestations, water availability early for healthy crop production. Thus, to get rid of these problems, the health condition of crops should be maintained properly.

In India, agriculture is the primary source of livelihood for about 58 % of India's population. More than 50 % of the Indian population is dependant either directly or indirectly on agriculture. Farming in India is mostly practiced in the rural area of the country. The agriculture sector accounts for 18 % of India's gross domestic product (GDP). It also employs 50 % of the country's workforce. Indian agriculture is very popular for producing crops like rice, wheat, jawar, bajra, maize, spices, and spice products. These crops are cultivated on a large scale in India. Thus, India is one of the largest crops producing countries in the world.

Remote sensing and GIS (Geographic Information System) technologies have been effectively used for monitoring several annual Indian crops like rice, wheat, maize, etc. Hence, evolving an approach for monitoring many crop cultivations using these advanced technologies has turned out to be a necessity. Geospatial data which is acquired by unmanned aerial vehicles such as satellites or drones can be used to detect and identify the health of crops. Remotely sensed imageries are used as mapping tools to categorize crops, examine their health, mapping of soil characteristics, and monitoring farming practices. Areas which are highly or moderately affected by insects and pests can be easily identified by the geospatial technology to apply the precise fertilizer or pesticide to an affected area of crop cultivation. It helps to improve the productivity of the land as well as lessens environmental influences. Remotely sensed images can be taken not only to identify diseases and infestations but also to monitor healthy crop fields.

Remote sensing and GIS technologies have numeral attributes that they contribute to assessing the health condition of many yields such as wheat, rice, maize, sugarcane, soybean, etc. One of the major advantages of optical (VIR) sensing is that it can see beyond the visible wavelength into the infrared, where wavelengths are highly sensitive to crop vigor as well as crop stress and crop mutilation. Remotely sensed images have been used not only to identify the unhealthy or stressed condition of crops but also to monitor healthy crop fields.

An excessive amount of chlorophyll is the content of healthy vegetation. Chlorophyll is the element that gives a distinctive green colour to the most vegetation. As chlorophyll absorbs the energy, blue and red portions of the electromagnetic spectrum reflect low in referring to healthy crops. In contrast, the green and NIR spectral portions reflect high. Lack of chlorophyll content can be seen in an infected, stressed, or damaged crop and its internal structure of the leaf also changes. As chlorophyll content decreases, the green region of the spectrum decreases in reflectance, as well as, NIR region reduces in reflectance due to internal leaf damage. Early detection of the crop infestation can be identified by these reductions in green and NIR bands. Examining the relationship between NIR and red wavelengths is a brilliant calculation of crop health conditions. This is the principle behind some vegetation indices, for example, normalized differential vegetation index (NDVI). NDVI value of a healthy crop is high because NIR reflects high and red light reflects low. The major aspects which are affecting NDVI are phenology and vigor. Variations in crop growth within one field can be examined. Zones and crops which are constantly healthy would appear uniformly bright. Among the brighter and healthier crop areas, infected crops would appear dark. A farmer can find the exact location of an infected area very easily and swiftly with the help of a GPS (Global Positioning System) unit. If a remotely sensed image is georeferenced, a farmer can match the coordinates of the infected area to that on the image by using a GPS unit. High-resolution images and multispectral imaging abilities are required to identify the damage or stress as well as to monitor a crop health conditions. Rapid reversal time from capturing data to the distribution of crop information is one of the greatest serious aspects in making imagery advantageous to farmers. An acquired image representing crop health of two weeks earlier would do not help to identify the damage. It is mandatory to capture images at a particular time in the growing season and regularly. Geo-spatial technology does not help farmers to reduce their fieldwork, but it assists to direct them to the zones which require immediate attention.

Study Area

The study area of this project is the Nashik district of Maharashtra, India. Nashik is situated in the northern region of the Maharashtra state of India. Nashik is one of the third major city of Maharashtra. Nashik is situated in the western ghats or Sahyadri range of the Deccan plateau which is formed by volcanic eruptions. Thus, the western region of Nashik is covered by many hills and mountains. The blocks of Nashik district are Dindori, Niphad, Igatpuri, Sinnar, Peint, Surgana, Baglan (Satana), Malegaon, Nandgaon Chandwad, Nashik, Manmad, Kalwan, and Yeola. Nashik is surrounded by some districts and state such as Dhule to the north, Jalgaon to the east, Aurangabad to the southeast, Ahmadnagar to the south, Thane to the southwest, and Gujarat state to the north directions. The approximate latitudinal and longitudinal extension of Nashik is in between 18.33° and 20.53° North and between 73.16° and 75.16° East (Fig. 1). It is around 700 meters above the mean sea level. The total geographical area of Nashik district is about 15,630 sq. km. (nashik.gov.in).

Nashik is known as the under-developing city in the state of Maharashtra, India. Therefore, Nashik has much demand in the agriculture industry. Nashik contributes highly to the international trade of agriculture products.

The total cultivable area of Nashik district is about 8,640 sq. km. The total actual sown area of the district is approximately 6587.63 sq. km. The total area which is uncultivable of Nashik district is 230 sq. km. As per the Government of Maharashtra, the small landholders of Nashik are around 3,50,96 (54%), the marginal landholders are around 2,88,496 (44%) and others are 3,210 (2%). Nashik district is very famous for certain irrigated crops such as sugarcane, grapes, onions and, other vegetables. The major source of irrigation in Nashik is the Godavari river. The Peninsular Godavari river is known as India's one of the largest rivers. Apart from the Godavari river, Vaitarna, Bhima, Girana, Kashyapi, and Darana are important rivers that flow throughout the district.

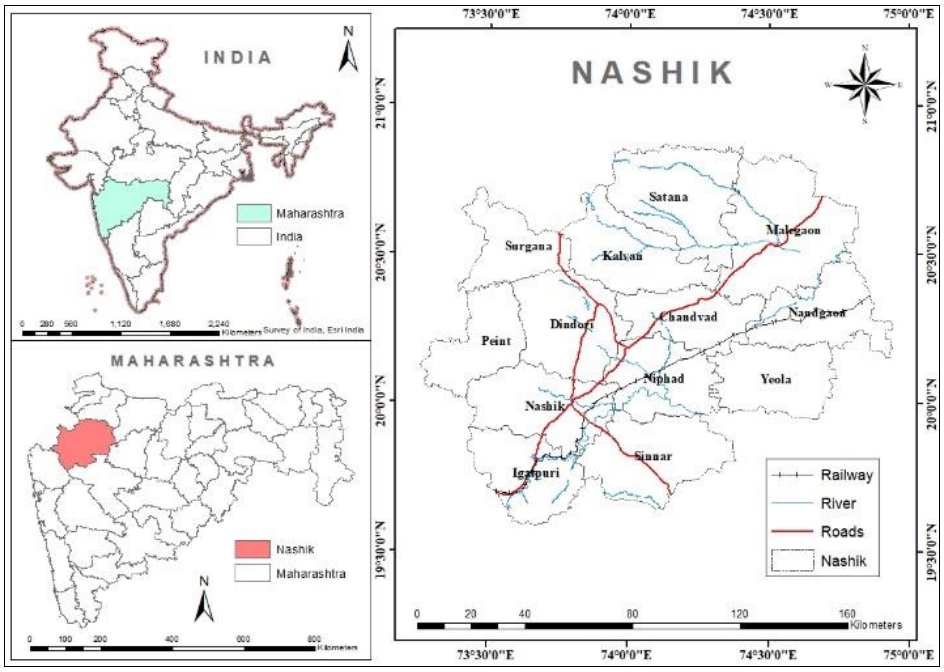


Figure 1: Study area

Materials & Methods

Collection of Geospatial data

Remote sensing and GIS techniques are used in this project work for the analysis of geospatial data. Data used for this project is earth observatory data which is acquired by the satellite platform. Images are captured with the satellite are remotely sensed images. Satellite images are downloaded year wise such as for the years 2013, 2015, 2017, and 2019 as per the interval of 2 years. Data is collected from internet web portals such as USGS Earth Explorer, GloVis – USGS (Global Visualization Viewer) (Table 1).

Table 1: Properties of satellite images

Sr. No.	Name of Satellite Product	Sensor	Spatial Resolution	Path/Row	Date of Acquisition
1	LANDSAT 8	Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS)	30 meters	147/46	28 November 2013
2	LANDSAT 8	Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS)	30 meters	147/46	01 October 2015
3	LANDSAT 8	Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS)	30 meters	147/46	07 November 2017
4	LANDSAT 8	Operational Land Imager (OLI) / Thermal Infrared Sensor (TIRS)	30 meters	147/46	07 November 2017

Ground data is collected using 'Google Earth Pro' software. Data that is collected is in the form of geographical coordinates. In this project, ground truth points were collected for the Nashik district to validate with the results. These collected ground points are used to measure the accuracy of the project's outputs. The unit of collected ground truth points is UTM i.e. in meters.

Methodology

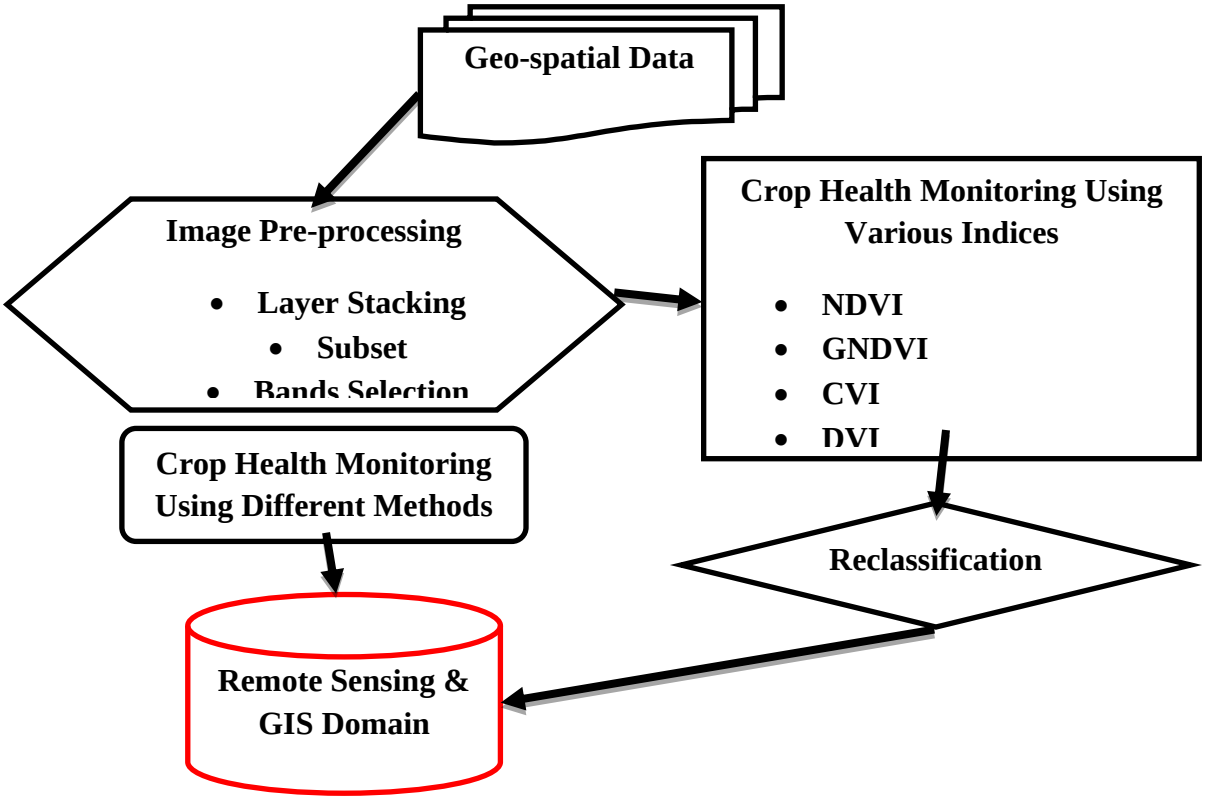


Figure 2: Workflow diagram

Vegetation Indices

Normalized Difference Vegetation Index (NDVI)

This is one of the most used vegetation indexes to measure the health of vegetation or crops. It measures the difference between the near-infrared band and the red band. The near-infrared band reflects the vegetation strongly and the red band absorbs the vegetation. The values of the NDVI always ranges from -1 to +1. Negative NDVI value i.e. -1 mostly indicates waterbodies. Values that are close to 0 indicate an urbanised area. Values closed to +1 indicates dense green leaves. The formula which is used to calculate NDVI values is;

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(\mathrm{NIR} + \mathrm{RED})} \qquad (1)$$

Green Normalized Difference Vegetation Index (GNDVI)

This vegetation index is used to estimate the photosynthetic activity and it is a commonly used index to determine water and nitrogen uptake into the plant canopy. It measures the difference between the near-infrared band and the green band. This vegetation index is very similar to NDVI. It is more sensitive to chlorophyll. GNDVI values could be in the range between -1 to +1, but they tend to be higher than that of NDVI values. This is because the wavelength in the green portion of the spectrum is shorter than the red portion. (Sudhanshu Sekhar Panda et. al. 2010) The formula which is used to calculate GNDVI values is;

$$\mathrm{GNDVI} = \frac{(\mathrm{NIR} - \mathrm{GREEN})}{(\mathrm{NIR} + \mathrm{GREEN})} \qquad (2)$$

Chlorophyll Vegetation Index (CVI)

This vegetation index is very helpful to represent the chlorophyll contains crops. Chlorophyll is an essential factor in the photosynthesis process of the plants. Healthy and unhealthy or stressed crop cover is depending on the concentration of the chlorophyll factor in crops or plants. It means, if the chlorophyll concentration in crops is higher, then, it is said to be healthy crops. While, if the concentration is less, then, it is stressed or unhealthy crop cover. CVI uses three bands to calculate the values; these are the near-infrared band, the red band, and the green band. The formula which is used to calculate CVI values is;

$$\mathrm{CVI} = \mathrm{NIR} * \frac{(\mathrm{RED})}{(\mathrm{GREEN})^2} \qquad (3)$$

Difference Vegetation Index (DVI)

This vegetation index is very fragile to soil background changes. This index is used to determine the difference between soil and vegetation. But it does not justify the alteration between reflectance and radiance produced by atmospheric effects or shadows. It could be functional to assess the vegetation's ecological environment. Hence, DVI is also known as EVI (Environmental Vegetation Index). It can be said that it is one of the easiest indices to calculate the values than any other vegetation indices. (Jinru Xue and Baofeng Su, 2017) DVI differentiates between the near-infrared band and the red band. The formula which is used to calculate DVI is;

$$DVI = NIR - RED \qquad (4)$$

Crop health based on NDVI values

Normalized Difference Vegetation Index (NDVI) is very useful to estimate the health of crops. NDVI is a method to measure healthy crop fields, as well as, unhealthy crop fields. NDVI is calculated in the range between -1 to +1. If the measured value is close to -1 or less than 0, it considered into a waterbody class. If the measured value is closed to 0, it is considered as urbanised area or no green leaves. If the value is close to +1, then, these are dense green leaves. High NDVI values, said to be as healthy crops, on the other hand, low NDVI values, said as unhealthy crops or no crop fields. The values measured in between 0-0.2, must be the land. And, values which are in between 0.2-0.5 must be as the soil mix vegetation. In the agriculture sector, most of the farmers find NDVI values useful for precision farming and to calculate the biomass. NDVI is also a good indicator of drought. (data.gov.in)

. Methods to monitor crop health condition

Merging of vegetation indices and reclassification

It is necessary to identify the health of crop fields for their major productivity and good quality content. Each of the indices used has its different perception to determine the health of crops. Thus, in this project, for better acknowledgment of crop health, all the mentioned vegetation indices are joined together. The process of joining all the indices is done through the 'Raster Calculator' tool in the 'ArcMap 10.5' software. Vegetation indices such as NDVI, GNDVI, CVI and, DVI are joined for all the 4 years. Then, these merged indices are reclassified to categorize its health condition using the 'Reclassification' tool. By following this method, the appropriate health condition of crops can be represented. The health condition is classified as healthy, moderately healthy, moderately stressed, stressed, and unhealthy crop fields. We can identify the health condition of crop fields of different areas of the Nashik district. This process is applied to the chosen talukas for this project.

Soil health & water balance

Soil is a very important source in the development of crops and their health. As it is mentioned earlier, the health of soils is very significant for crop health and its yield production. Healthy soil plays a vital role in making crops healthy. If the health of the soil is poor, it affects crop growth as well as crop health. Hence, it causes to minimize crop productivity.

Besides, it is necessary to balance rainwater and other irrigation techniques for delivering water to the crops. Rainfall is a very important factor in crop health. But it should be in an absolute amount in any growing season for its health. If the average rainfall is in a lesser or higher amount, it can result in many crop and soil health issues.

Change detection and identification

Change detection is the process to identify and to determine the differences in selected images. It is a method or a technique to recognize how and where the area is changed or what types of differences are seen. The change detection process can be done through the 'ERDAS Imagine 2014' software, as well as, from 'ArcMap 10.5' software. In this project, changes in crops are detected and identified using the 'Image Difference' tool with the help of 'ArcMap 10.5' software. The process is done to analyse the changes that occurred in crop fields of the Nashik district for a period of 7 years such as from 2013 to 2019.

Results

Vegetation indices

In the map of NDVI, the lush green healthy crops are seen in the middle and western regions of Nashik. The healthy crop condition is seen in Dindori, Niphad, Nashik, and Igatpuri region. The stressed vegetation is observed in Chandwad, Yeola, Nandgaon, and Sinnar blocks of the district. The GNDVI map shows as the photosynthetic activity and water and nitrogen uptake into the plant canopy, it can be observed that the green vegetation has covered almost every block of the district. CVI map represents the chlorophyll concentration within the crops of Nashik. As it is seen that the health of crops and vegetation of the district is very poor as it shows the stress almost all over the blocks. The map represents the soil background of the district. The soil is observed much healthy in the western region of the district such as in Dindori, Niphad, Nashik, Igatpuri, Peint, Surgana, Kalwan, and Satana blocks. It is identified poor in Malegaon, Chandwad, Yeola, and Sinnar blocks following the results (Fig. 3).

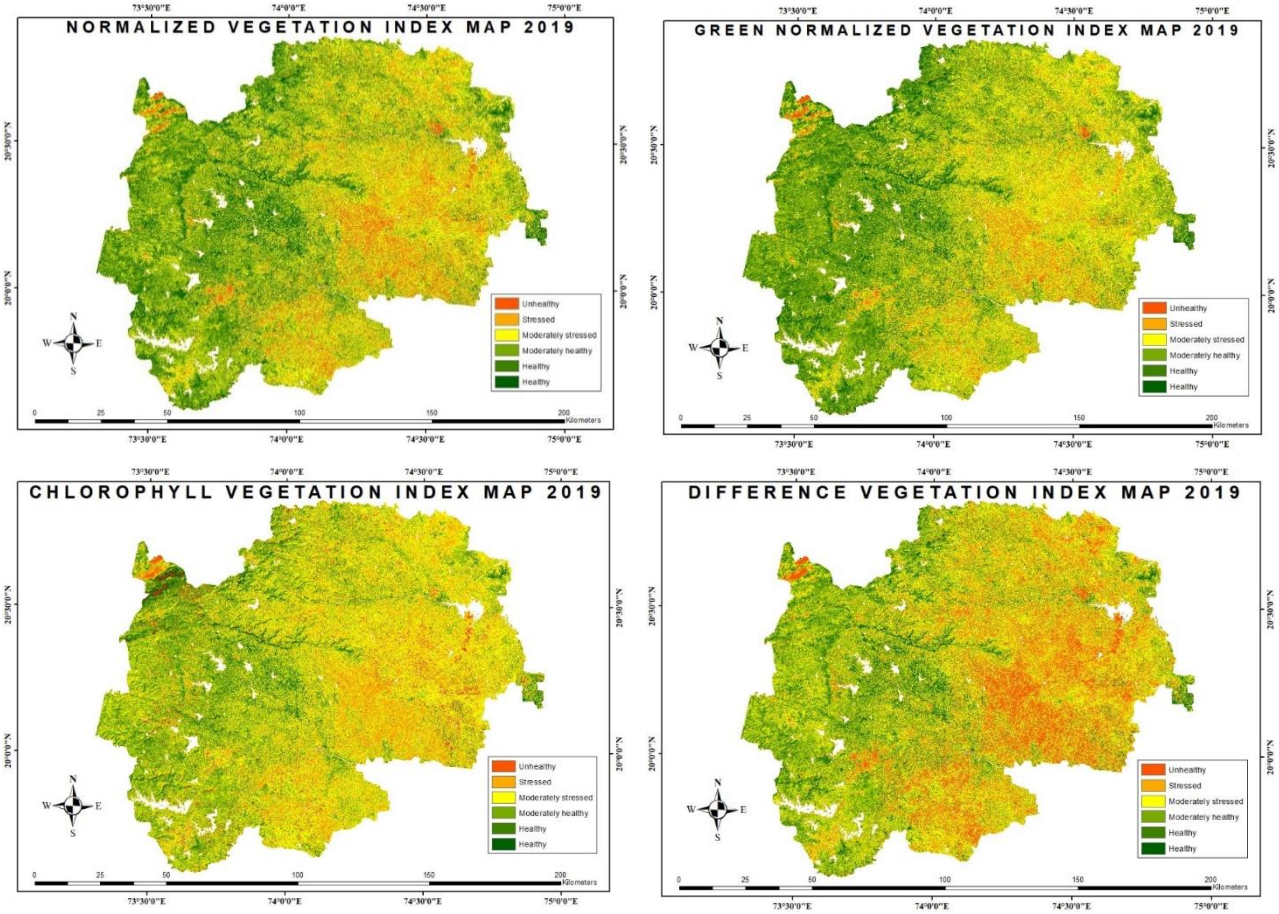


Figure 3: Vegetation indices used to monitor the health of crops for 2019

Crop health based on NDVI values

The above figure represents the crop health based on average NDVI values of the Nashik district. From the figure 4, it can be analysed that talukas such as Niphad, Nashik, and Dindori has highly healthy NDVI values that are very suitable for growing crops. Talukas which are stressed or highly unhealthy are Malegaon and Nandgaon are not very suitable to cultivate the irrigated crops. Others are moderately healthy or unhealthy which are suitable to grow a particular crop (Fig 5).

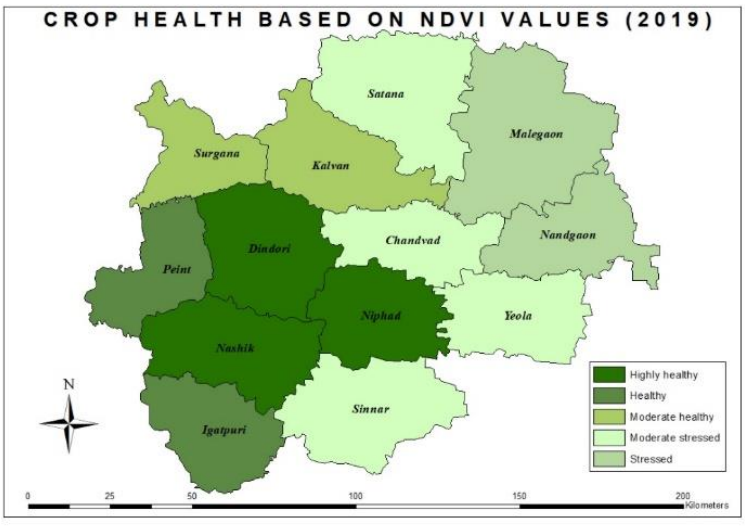
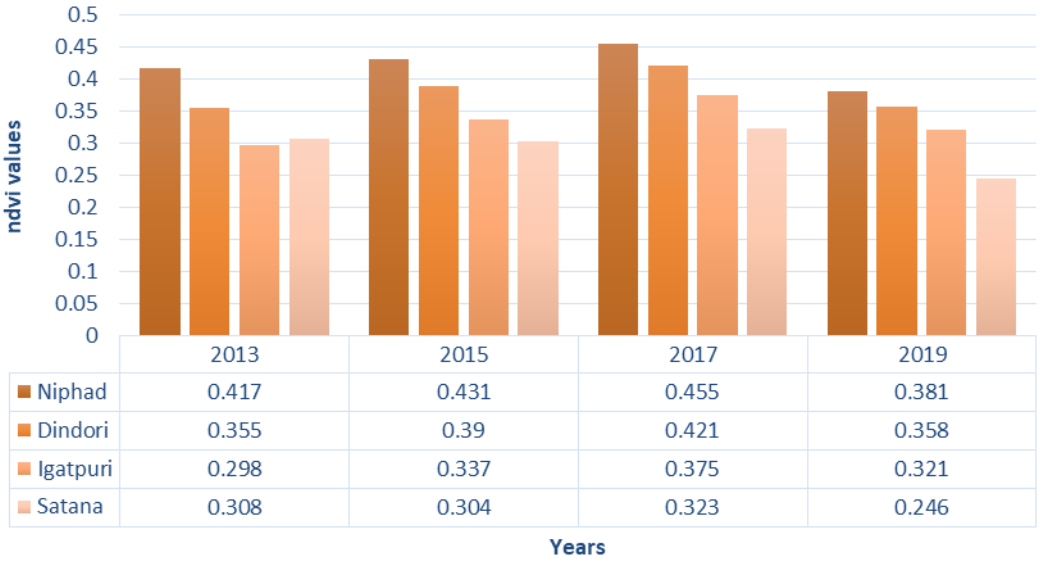


Figure 4**:** Crop health based on NDVI values



	2013	2015	2017	2019
Niphad	0.417	0.431	0.455	0.381
Dindori	0.355	0.39	0.421	0.358
Igatpuri	0.298	0.337	0.375	0.321
Satana	0.308	0.304	0.323	0.246

Figure 5: Average NDVI values from 2013 – 2019

Changes in crop health condition

Dindori

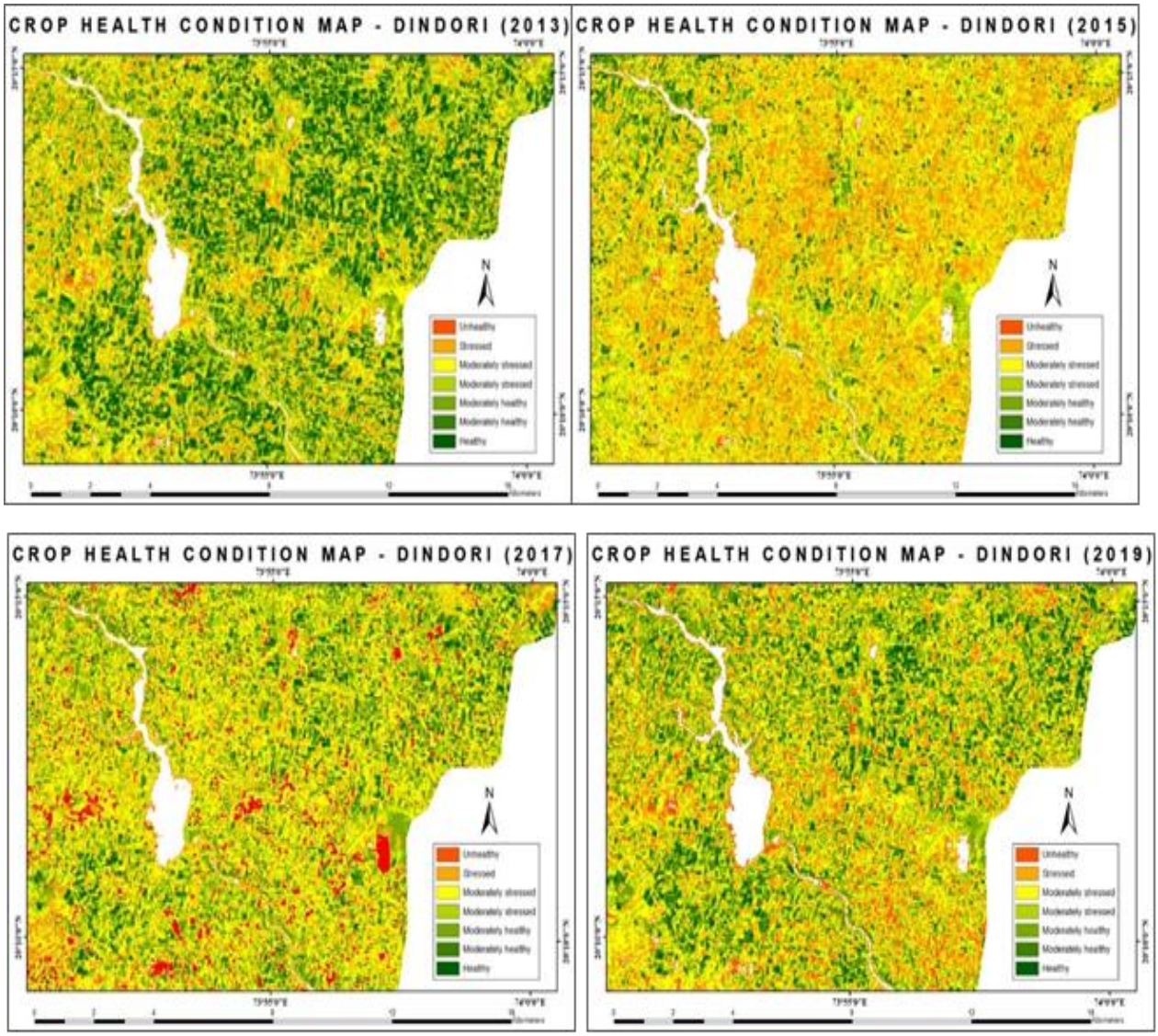


Figure 6: Crop health condition map for Dindori from 2013 to 2019

According to the crop health results, it is analysed that the health condition of crops is much healthy in the Dindori block in 2013 (Fig 6). But it rapidly decreased in 2015. Then, gradually increased in 2017 and 2019 years. The changes in crop health of Dindori are due to less rainfall in 2014 and 2015 years. Also, it received heavy rainfall in 2018 and 2019 years. Thus, the health among the crops observed increased.

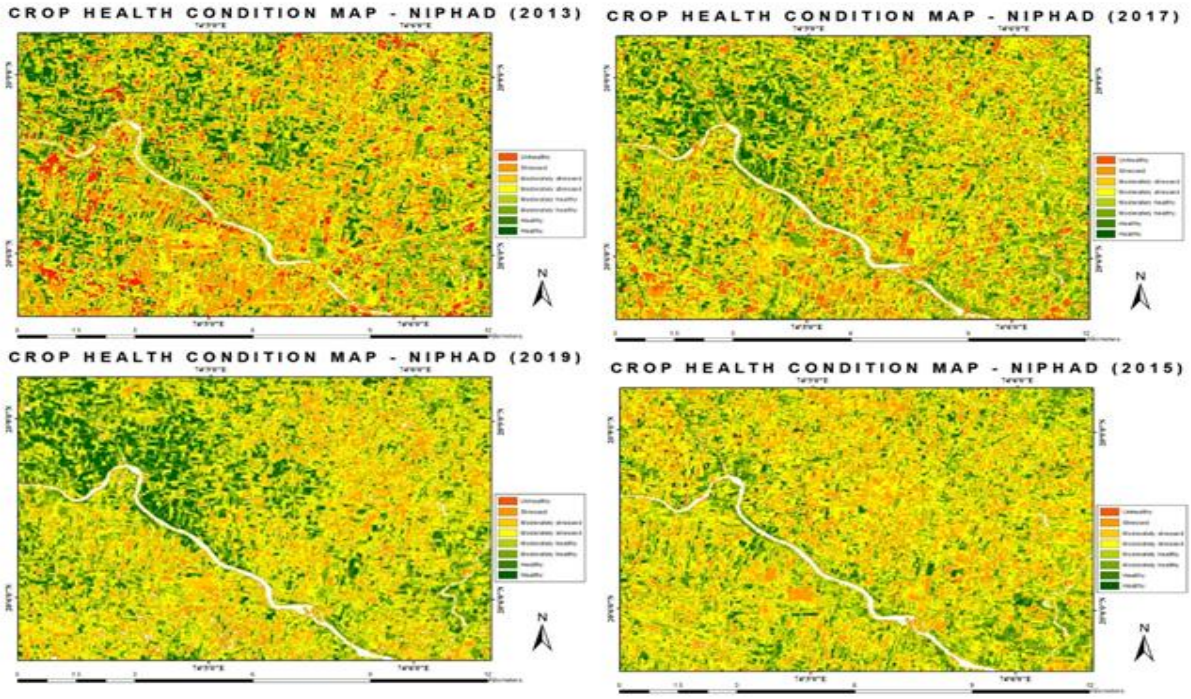


Figure 7: Crop health condition map for Niphad from 2013 to 2019

The health of crops observed improved in the Niphad block of the district. As compared to 2013, the health condition of crops in Niphad is noticed healthy and seems incremental in its health (Fig 7). This is might be due to heavy rainfall in recent years all over the Nashik district.

Igatpuri

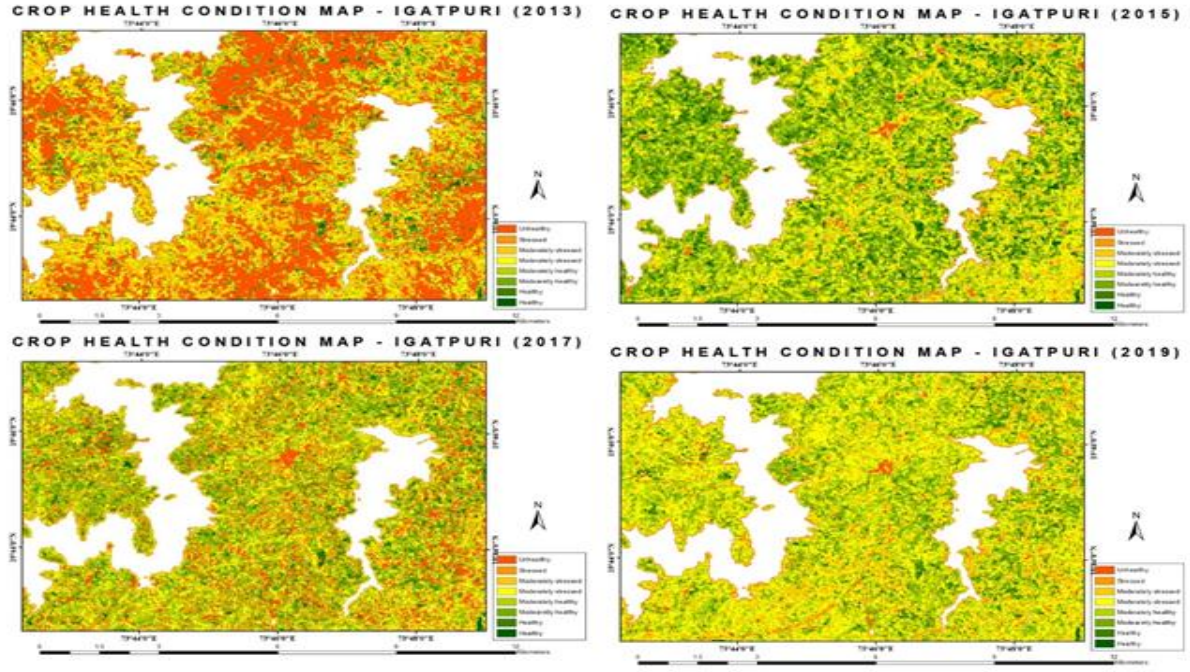


Figure 8: Crop health condition maps for Igatpuri from 2013 to 2015

The stress is observed all over the map is due to the lack of dense forest in the mountainous region of Igatpuri. Crop cover is seen near the water bodies of the map. In 2013, as per the results, the health condition of crops is

very stressed and moderately stressed. The few of them are noticed healthy on the map. In 2015, the health of crops observed much improved in Igatpuri. Healthy and moderately healthy crops are seen all over the map than stressed crops. In 2017, crop health is observed to decrease in Igatpuri than in 2015 (Fig 8). Some unhealthy crops and stressed crops as well can be identified from the map. In 2019, the health condition of crops is noticed improved. It can be analysed that crops are in more healthy condition than the stressed condition.

This is because of Igatpuri is a hilly and mountainous region and mostly rice crop is cultivated in this region. Thus, the rice crop needs much water than any other crop. Rice crop is dependent on the rainfall. The lack of rainfall leads to poor health and poor growth of the crop.

Satana

In 2013, the health condition of crops can be noticed unhealthy than moderately stressed and healthy crops in Satana block. After 2 years, improvement in the health condition of crops can be determined. In 2015, healthy crops are observed near a river and stressed crops seem in other regions of the map. In 2017, crop health is observed to decrease than in 2015. Crops are noticed majorly as unhealthy and stressed all over the map. The health condition of crops is observed much improved in 2019 than in 2017. Healthy, moderately healthy as well as stressed crops are observed in Satana block for 2019.

The health condition of crops in Satana taluka of the Nashik district is improved in these 7 years such as from 2013 to 2019 (Fig 9). Mostly, the tribal community is located in the Satana region. As per annual rainfall records, Satana receives medium rainfall per year.

From all of the above processed images, the health condition of crops is analysed to be improved. The health of crops observed getting better by the years in every chosen talukas of the district. The major cause observed for the improvement in crop health is rainfall measurement.

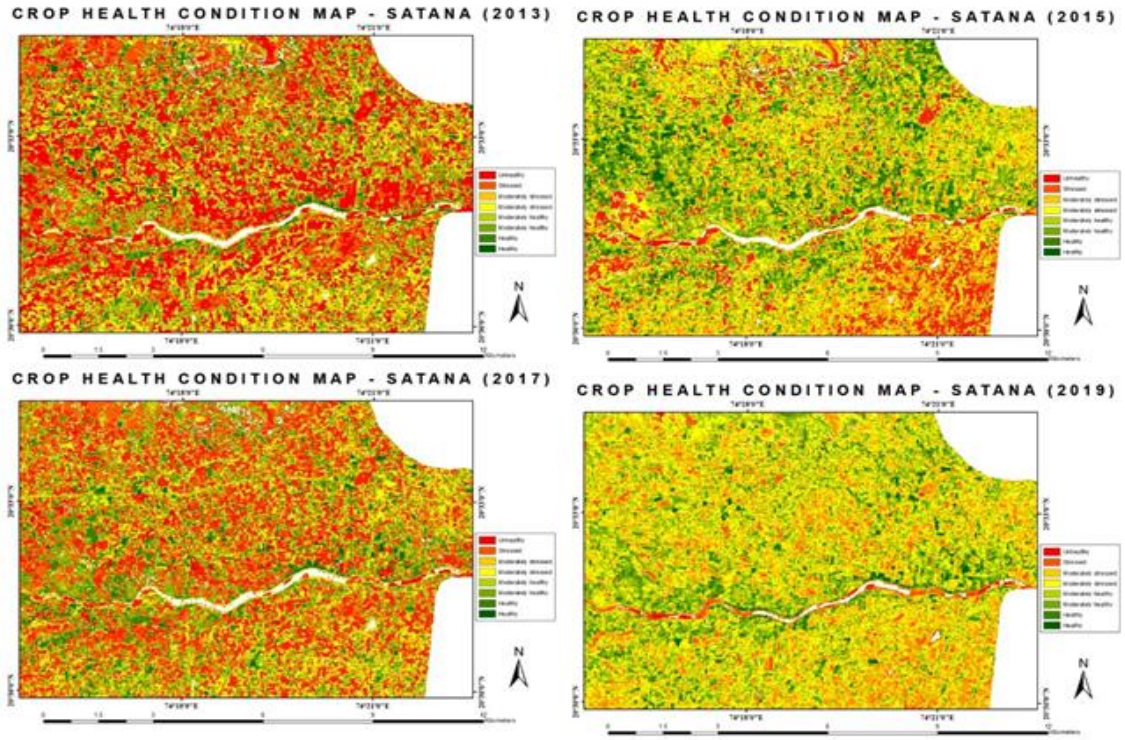


Figure 9 Crop health condition maps for Satana from 2013 to 2015

Soil health

The temperature of soils is also affecting the growth and the health of crops. An increase in temperature can severely affect soil health as well as crop health.

The equation which is used to measure the soil temperature is;

$$\boldsymbol{Temperature\ (T) = TB/[1 + \left(\lambda \times \frac{TB}{c2}\right) \times \ln(e)]} \qquad \textbf{(5)}$$

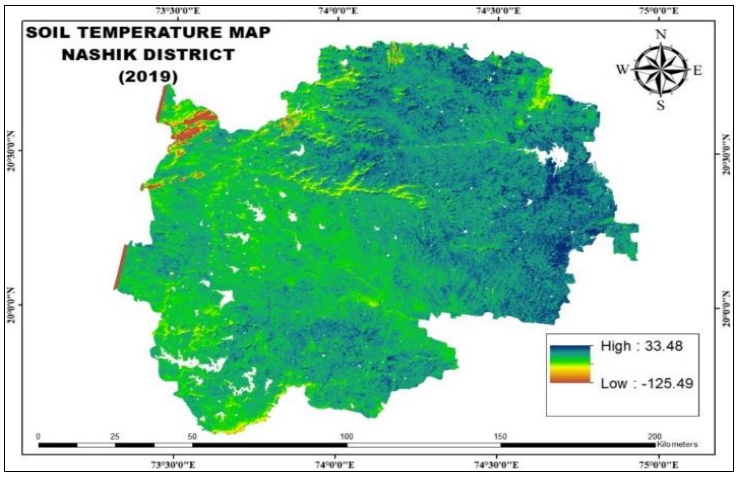


Figure 10: Soil temperature map of the Nashik district for 2019

The above figure 10 represents the soil temperature of the Nashik district in the month of November 2019 year. As per the result, it can be analysed that the soil temperature in the agriculture region has a medium temperature. The medium temperature is observed in Dindori, Niphad, Igatpuri, Peint, and Surgana blocks of the district. Also, the open land region has a high temperature i.e. around 33.48° C in the district for 2019. The blocks which are coming under the high-temperature region are Malegaon, Nandgaon, Sinnar, Satana, Kalwan, and Chandwad in Nashik.

Crops need essential nutrients and water in an adequate amount and proportions for healthy crop growth. Soils provide all these essential nutrients to crops. Crop health condition is partially dependant on the soils. The soil must be fertile to cultivate crop yield. A fertile soil usually contains nitrogen, phosphorous, and potassium. These are the major nutrients for crop nutrition. As well as, fertile soil also needs calcium, magnesium, sulphur, iron, zinc, copper, etc. An application of organic fertilizers can be beneficial to increase the soil nutrients.

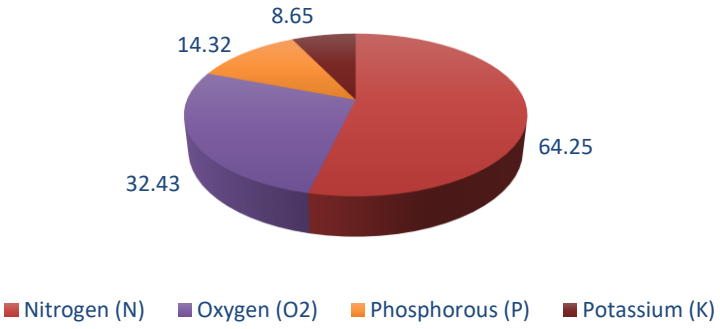


Figure 11: Soil deficiency in terms of nutrients

The chart given above shows the availability of soil deficiency in terms of nutrients in the Nashik district (Fig 11). Nitrogen content in the district is much in quantity. Nitrogen helps to increase the growth rate of the crops and hence, its productivity.

Change detection

The figure 12 represents the changes in crops cover from 2013 to 2019 years in an interval of 7 years. As I have taken 4 agriculture prone talukas in this project to monitor the health condition of crops in Nashik district. We can acknowledge more to monitor the health condition of crops by this process. We can understand that which crop field is stressed or which is healthy in these selected years. In these changes of crop cover maps, leaf green colour shows an increase or improvement in crop health, light green colour shows the moderate or constant health condition, and orange or red colour shows decreased health in crop cover.

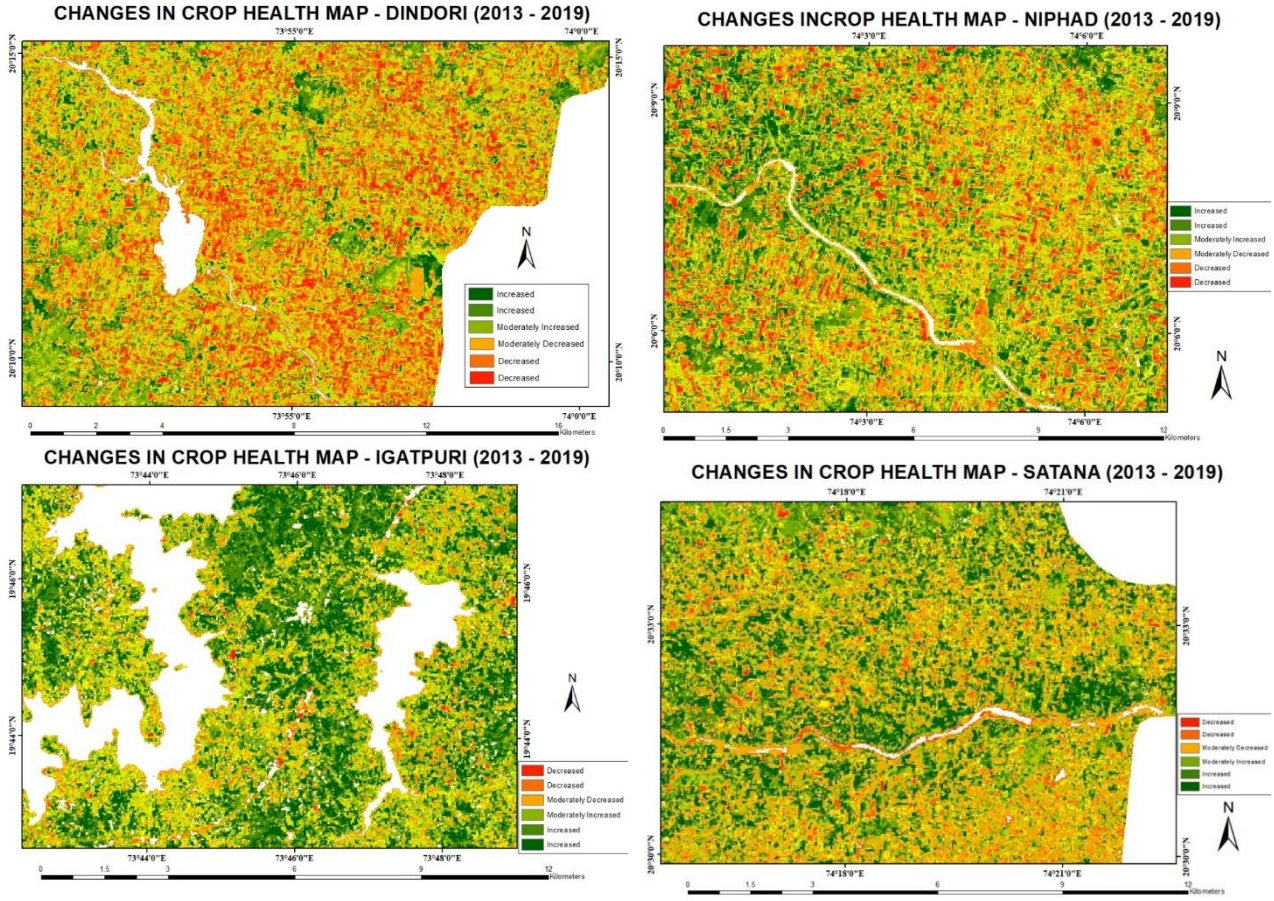


Figure 12: Changes in crop health of talukas from 2013 to 2019

From the above figure 12, it can be concluded that the health condition of crops is decreased from 2013 to 2019 years. The few crops are seen as improved in their health. From 2013 to 2019, the health of crops is observed increased in Niphad block. Some of them have lost their health as they represent as decrement in their health. In Igatpuri, the health of vegetation as well as crops is observed increased from 2013 to 2019 in the map. But some crop fields can be noticed that they reduced in their health. The health of crops is analysed as improved near a river in Satana block from 2013 to 2019. Also, it is seen as decreased in the other region of the map. As per the results, the changes observed in the chosen blocks of the district are due to the application of chemical fertilizers for the development of crops and their yield productivity. As well as, as mentioned earlier, the district records low rainfall in 2014 and 2015.

Validation of crop health with ground points

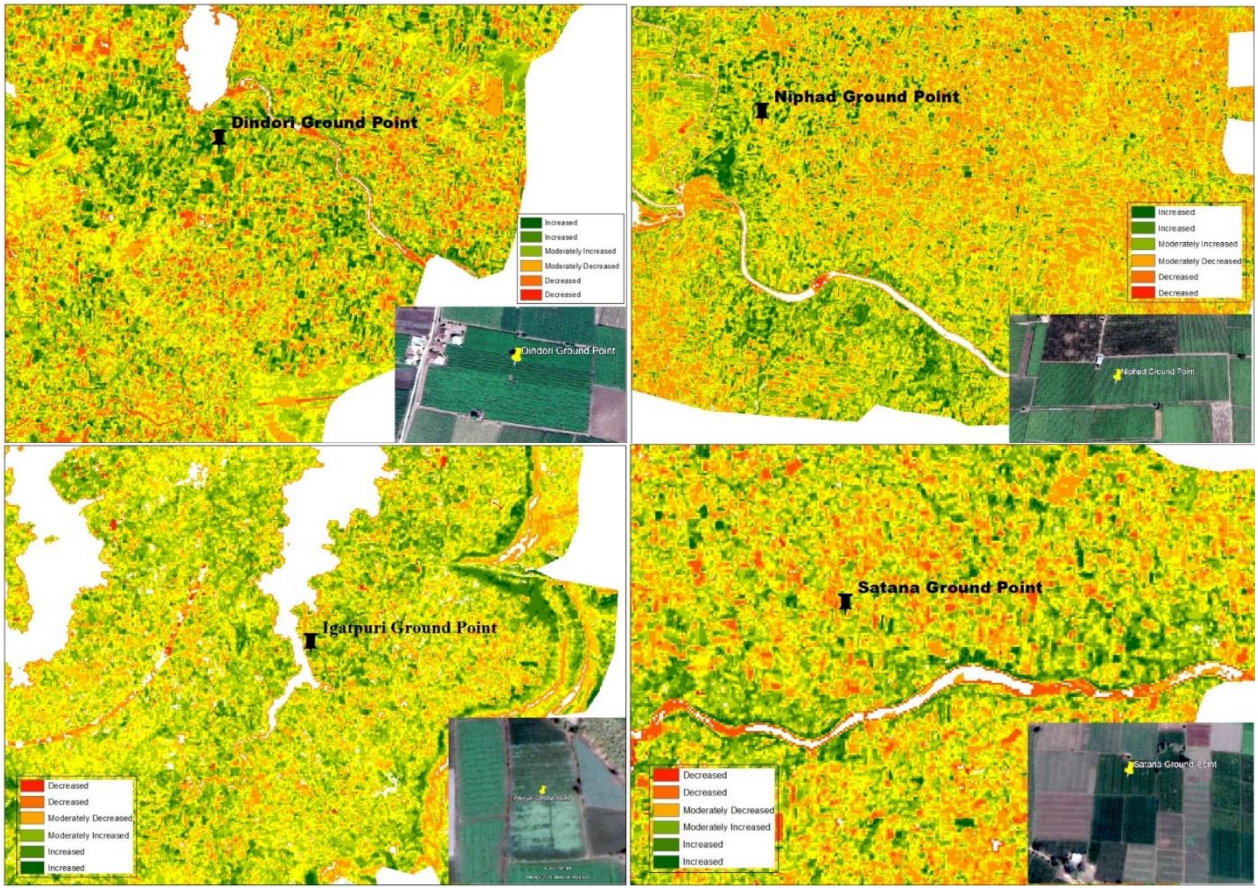


Figure 13**:** Validation of crop health with ground points for selected regions

To declare an output of the project acceptable and to check the accuracy, it is very important to use the validation process. It means to validate ground truth points with the results. Thus, measuring its accuracy approximately. The process is done for consideration of the project's results.

Conclusion

The project is done to monitor and the determination of crop health condition in some agriculture prone talukas of the Nashik district for 2013 to 2019 years. One of the major objectives of this project is to make aware of geospatial technologies to the farmers. As well as, to monitor the crop health condition of Nashik district by using these advanced technologies. Thus, I used remote sensing and GIS technologies in this project to fulfil the project's objectives. The differences in crop health and its coverage from 2013 to 2019 are due to the application of chemical fertilization on crops, the amount of annual rainfall in the district and organic or inorganic farming practices, etc.

The results of this study indicate the usage of remote sensing and GIS technology is very advantageous in agriculture. These technologies can be used by farmers to collect the data and its analysis, regularly monitoring crop fields for maintaining their health. Many vegetation indices are very helpful to observe healthy, stressed, or diseased crops. This information is very essential that should be delivered to farmers for better productivity. Geospatial data is a valuable tool in the agriculture industry to increase profitability and healthy crop production.

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Ethical approval: Not applicable

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