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Cotton Crop Yield Estimation Using Multi Spectral Data in GIS Environment: A Comparative study from Amravati Tehsil for Year 2023-2024

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ABSTRACT: Accurate and timely prediction of cotton crop yield before harvesting offers significant advantages to researchers, producers, government agencies, and policymakers, enabling better economic planning and efficient responses to natural calamities. Remote sensing and GIS technologies play a critical role in providing consistent and reliable yield estimations. This study aims to generate precise pre-harvest yield estimates of cotton using satellite data integrated with machine learning, remote sensing, and GIS techniques. Cotton, a key kharif crop, thrives under Maharashtra's favourable climatic and soil conditions, making it a major cash crop for the region. A comparative analysis of cotton yield estimation for 2023 and 2024 in Amravati Tehsil was conducted using Sentinel-2 satellite imagery and NDVI-based classification. The NDVI provided insights into natural vegetation, crop extent, and urbanization patterns. Separate classification was carried out for cotton, natural vegetation, urban areas, barren land, water, and other crops. Ground truth data validated minimum, maximum, and average yields. Findings indicated an improvement in classification accuracy from 86.60% (2023) to 88% (2024) and an increase in estimated average yield from 45,076.9 to 51,150 tonnes. The study highlights that sustained multi-year satellite monitoring enhances agricultural forecasting, revealing improved crop health and productivity in 2024 due to favourable environmental conditions.

KEY WORDS: Crop Yield, Comparative Yield Analysis, GIS, NDVI, Sentinal-2, Cotton.

I. INTRODUCTION

In India Agriculture is most significant land use activities. GIS, and Remote Sensing technologies have multiple applications in Agriculture sector, enabling accurate as well precise monitoring of crops, monitoring soil health, monitoring of water conditions, precision farming, predicting climate changes and many more. Remote Sensing and Agriculture are closely linked, with this technology relying on UAVs and satellites (Dragaonfly Aerospace, 2022).

This study builds upon previous research conducted in 2023 and extends the methodology to the year 2024. Comparative analysis allows us to examine changes in NDVI and yield, helping understand temporal dynamics in cotton productivity. Cotton *(Gossypium)* is among the important cash crops specifically in Maharashtra, providing 35% of total fibre for the textile industry, including fine paper. It also plays significant role in the oil industry and livestock feed production, as its seeds are rich in oil (8-14%) and protein (20-40%). Accurate pre-estimation of Cotton yield is essential for future import and export planning. It influences market price trends and helps farmers make better decisions on field operations such as harvest transportation and storage of Cotton [1]. Cotton plays foremost role in industrial sector in India especially in Maharashtra. Cotton is principal natural textile fibres worldwide. Cotton is a staple (soft) fibre that grows on the surface of seeds, covered by pods known as bolls. The primary components influencing the economic yield of Cotton are boll weight and Cotton bolls quantity. These traits are essential in determining the functioning and overall performance of the Cotton crop during its final stages of growth [2].

Need for calculating crop yields prior-harvesting is vital in minimizing the influence and consequences of natural tragedies, to ensure food security, to estimate market prices for agricultural goods and reducing poverty. Early yield forecasts enable policymakers and decision-makers to assess necessary import or export levels. Climate change induced natural occurrences, like sudden heavy upstream rainfall causing flash floods, often damage Cotton Yield. Hence, predicting crop yields before harvest becomes essential in curtailing losses, achieving intended yields, and maximizing profits [3].

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II. RELATED WORK

Several institutional works align very well with study on NDVI-based, multi-year cotton yield estimation in Maharashtra using satellite and climate variability. Huang et al. used very high-resolution small-UAV imagery and plant height metrics to accurately estimate cotton yield, demonstrating that low-altitude remote sensing can provide reliable, pre-harvest yield estimates at field scale [4]. Another review article on crop yield prediction in agriculture (2024) highlights the integration of remote sensing indices such as NDVI with machine learning to forecast yields under variable climate, reinforcing the value of temporal NDVI analysis between 2023 and 2024 seasons [5]. These works collectively reinforce the scientific basis of your statements on the importance of pre-harvest cotton yield estimation, the tight linkage between NDVI and cotton productivity, and the growing role of satellite and UAV platforms (including commercial constellations) in Indian agricultural monitoring.

III. STUDY AREA

The research area Amravati Tehsil is one of the tehsils of Amravati District, situated in the state of Maharashtra. The study region comprises of 901.11 sq. kilometres. The environment of Amravati is hot and humid; thus, it is best suited for Cotton. In summers temperatures can reach up to 46°C (120 °F). The area lies between Longitude 76.74°E to 78.02°E and Latitude 20.93°N to 21.14°N (Figure 1). Agricultural land of the region is dedicated to Cotton cultivation, which is one of the primary crops in the Amravati Tehsil. The region receives an average annual rainfall of 700 to 800 mm, a crucial factor influencing Cotton yield [6]. Understanding the association among rainfall range and Cotton crop performance is essential for accurate yield estimation and optimizing agricultural practices. This rainfall level characteristically supports ultimate growth of Cotton, however variations within the rainfall range can effectively change yield outcomes. Fluctuations in the timing and delivery of rainfall during the growth period of cotton influence crop quality. In addition to this, the soil in the region is primarily black Cotton soil, which plays a significant role in moisture retention and overall crop productivity. This soil is rich in nutrients, enhancing the growth potential of Cotton crops [7]. These climatic factors and soil conditions in Cotton cultivation provides valuable insights for addressing specific agricultural challenges in Amravati Tehsil associated to Cotton cultivation.

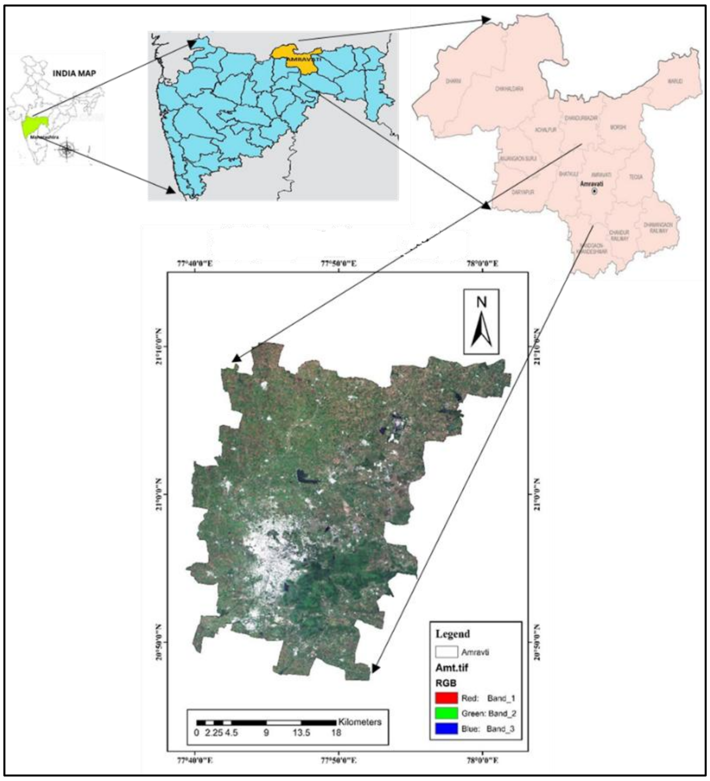

Figure 1. Study Area Map of Amravati Tehsil

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IV. DATA AND MATERIAL

Cotton crop yield estimation utilizes multispectral data, specifically Sentinel-2 data featuring bands 2, 3, and 4—blue, green, and red respectively—used for crop sampling within the software. The Sentinel-2 imagery, was acquired and analysed using GEE (Google Earth Engine) from the period between October 1st to October 10th, for both 2023 and 2024 with a cloud cover of less than 1%. For each year, separate NDVI (Normalized Difference Vegetation Index) calculations and supervised classifications were performed, enabling a year-wise analysis of crop health, land use, and cotton yield. Before analysis, the data underwent atmospheric correction to ensure accuracy. The shapefile used in the research was sourced from the Survey of India's free dataset, while government reports provided area production statistics for survey data. Microsoft Excel was employed for statistical analysis. NDVI was derived from Sentinel-2 imagery, while Landsat data from USGS was used for accuracy validation. Additionally, topographical data, including elevation and slope, were integrated to refine yield estimates of crop. ArcGIS tools, including Spatial Analyst and Model Builder, facilitated the processing and analysis of geospatial data, enabling crop sampling and classification within ArcGIS software version 10.8. This dual-year analysis enabled a comparative understanding of cotton cultivation dynamics under similar methodology but different environmental conditions. This two-year analysis ensures comparability by using identical methods across distinct growing seasons.

V. METHODOLOGY

By leveraging Sentinel-2 imagery in ArcGIS 10.8 software, it is feasible to create accurate maps of Cotton-growing agricultural land in Amravati Tehsil. The Sentinel-2 data is acquired through Google Earth Engine, which provides a valuable resource for researchers with its precise high-resolution images. The Sentinel-2 data are utilized in this study to classify crop types with high precision and to monitor crop growth. With spatial resolution of 10 meters, Sentinel-2 data provides intricate details about various crops, enabling more precise analysis and differentiation between various agricultural fields. The research methodology involves integrating Sentinel-2 information with ground survey data and Landsat data to generate highly accurate and precise maps. This approach correlates visual signs obtained from ground observations (Figure 2) with class signatures, offering an effective framework for agricultural land monitoring and mapping [7].

Estimating the crop yield of Cotton and creating class signatures in images are accomplished using ArcGIS version 10.8. Supervised classification of Sentinel-2 time-series data was conducted for the Kharif season of the year 2023 and 2024, spanning from October 1 to October 10. This approach allows for the manual categorization of the data for comparative analysis into six distinct classes: Cotton crop, natural vegetation, Other crops, Settlement area, Water body and Barren land, based on spectral characteristics of each class (Figure 4). The resulting classifications provide a detailed understanding of the unique spectral properties of each class, allowing for a more accurate classification of crops and other land-use categories [7].

Following the crop classification, we have generated a NDVI (Normalized Difference Vegetation Index) image (Figure 5), which offers valuable insights into the health and density of vegetation in the area. This is achieved by analysing the reflectivity of light in visible and NIR (near-infrared) wavelengths, which is a well-established method for measuring vegetation in the study area [8]. To confirm the accuracy of our classification, we equated the results with Sentinel-2 data and Landsat imagery along with calculation of overall accuracy and Kappa accuracy (Table3). The entire classification and yield estimation methodology was repeated for the year 2024 using updated Sentinel-2 imagery and fresh ground survey data.

Figure 2. Ground observations for cultivation of Cotton and Ground Yield data collection

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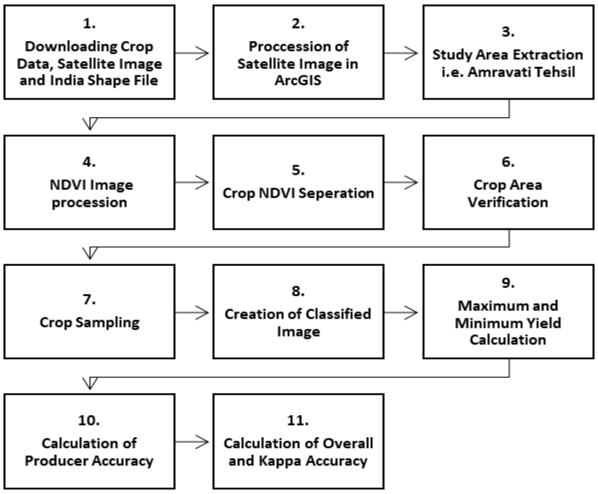

Figure 3. Methodology used for Research

VI. RESULTS AND DISCUSSION

The research area has been classified into six distinct classes and the analysis of satellite imagery reveals that a significant portion of land in Amravati tehsil was dedicated to Cotton crop in 2023-2024. This information is depicted in the classified map (Figure 4) processed on Sentinel-2 data (satellite imagery). The ArcGIS mapping software played a crucial role in this process, enabling the mapping, analysis, processing, collaboration and sharing of data. Additionally, ArcGIS facilitated the visualization of satellite data, offering valuable insights into spatial distribution of land-use patterns along the study area. The primary objective of the research is to estimate the yield of Cotton crops in the Amravati tehsil. The yield is directly correlated with the NDVI, which is widely accepted metric for measuring vegetation density. In this study, high NDVI values specify dense vegetation, while low NDVI values shows settlement areas and extremely high NDVI values shows natural vegetation. To assess the accuracy of findings, calculation of percentage accuracy is performed by relating observed and simulated values of Cotton cultivation. The observed value was taken from a survey report, which provided the total cultivated area of Cotton in Amravati in hectares. The simulated value was calculated using ArcGIS software (Table 3). The classification of Sentinel-2 imagery for 2024 revealed extensive cotton cultivation across Amravati Tehsil. NDVI analysis confirmed higher vegetation density than in 2023 (Figure 5).

Table 1. NDVI Metric calculate values for year 2023 and 2024

NDVI Metric	2023	2024
Minimum NDVI	-0.3098	-0.2524
Maximum NDVI	-0.0751	-0.1284
Average NDVI	-0.1924	-0.3808

Table 2. Yield Estimates for Cotton in tons for 2023 and 2024

Yield Estimate	2023 (tons)	2024 (tons)
Minimum Yield	30,051.3	34,500.0
Maximum Yield	60,102.5	67,800.0
Average Yield	45,076.9	51,150.0

The results indicate that the total cultivated area of Cotton in the study area is approximately 24,041 hectares (simulated value), as calculated using ArcGIS 10.8 (Table 3). In contrast, the observed value of total cultivated area of Cotton from survey report of the Amravati district in 2019-2020 is 2,76,078 hectares, which represents the total area of Cotton

cultivation in the district. The NDVI values obtained from our analysis range from a maximum of -0.1284 to a minimum of -0.2524, with an average value of -0.1924. Using these values, we calculated the maximum possible yield of Cotton for the Amravati tehsil to be 67,800.0 tonnes (Table 2) and the minimum possible yield to be 34,500.0 tonnes (Table 2) thus average yield is 51,150.0 tonnes. The simulated area under cotton cultivation remained at approximately 24,041.1 hectares. However, increased NDVI values indicate better crop health and density, possibly due to improved rainfall patterns or shifts in sowing time.
Research successfully interrelated ground signatures by class signatures during the matching process, there by establishing strong resemblance among class signature and Landsat data thus confirming match with crop type. To evaluate overall accuracy of the matching process, we established a set criterion for spectral correlation resemblance i.e., if a comparison satisfies the composed Kappa Accuracy measure the functioning of classification i.e., how precise and accurate the classification is performed which shows 91.77% which is more than 2023 (89.88%). The calculated Overall accuracy of study is 88% and that for 2023 was 86.60% which is complete number of accurately classified pixels to the total number of reference pixels. Thus, overall accuracy of correctly classified Cotton is 90% (Table 3), Natural vegetation is 85%, Water is 100% (Table 3), Settlement is 100% (Table 3), Barren Land is 81.42% (Table 3), Other crops is 85.71% (Table 3). The corresponding class is said to be accurately line up with the ground reality (Figure 2).
This method confirms the dependability of the classification outcome and enhance the overall precision of our crop type map hence providing trustworthy and precise representation of Agriculture landscape. Producer Accuracy is number of properly classified pixels in every category to entire number of classified pixels in that class. The producer accuracy of Cotton is 88.88%, Natural vegetation 100%, Water bodies is 100%, Settlement 100%, Barren land is 83.33% and Other crops is 88.88% (Table 3).

$$Over\ all\ Accuracy = \frac{Total\ Number\ of\ Correctly\ Classified\ Pixels}{(Diagonal\ Total\ Number\ of\ Reference\ Pixels} \times 100$$ [9]

$$Producer\ Accuracy = \frac{(\ Number\ of\ Correctly\ Classified\ Pixels\ in\ each\ Category)}{Total\ Number\ of\ Reference\ Pixels\ in\ that\ Category\ (The\ Column\ Total} \times 100$$
[9] .

$$\text{Kappa Accuracy} = \frac{(\ (\text{TSxTCS}) - \sum(\text{Column Total x Row Total}))}{(\text{TS2} - \sum(\text{Column Total} - \text{Row Total}))}$$ [9]

Table 3. Over all Accuracy and producer Accuracy of classified classes (2024)

Sr.no	Classified Classes	Overall Accuracy	Producer Accuracy
1	Cotton	90%	88.88%
2	Natural Vegetation	85%	100%
3	Water Bodies	100%	100%
4	Settlement	100%	100%
5	Barren Lands	81.42%	83.33%
6	Other Crops	85.71%	88.88%

Table 4. Over all Accuracy and producer Accuracy of classified classes (2023)

Sr.no	Classified Classes	Over all Accuracy	Producer Accuracy
1	Cotton	87.5%	77.77%
2	Natural Vegetation	75%	100%
3	Water Bodies	100%	100%
4	Settlement	100%	100%
5	Barren Lands	71.42%	83.33%
6	Other Crops	85.71%	66.66%

The 2024 season showed improved cotton yield, higher vegetation density, and better classification accuracy, likely due to favourable climatic conditions and early sowing. The NDVI results and supervised classification showed stronger alignment with ground truth in 2024 than in 2023. (Table 4)
The classification accuracy for 2024 improved from 86.60% to 88.00%, and the producer accuracy for Cotton increased from 77.77% to 88.88%, indicating better mapping outcomes in 2024.

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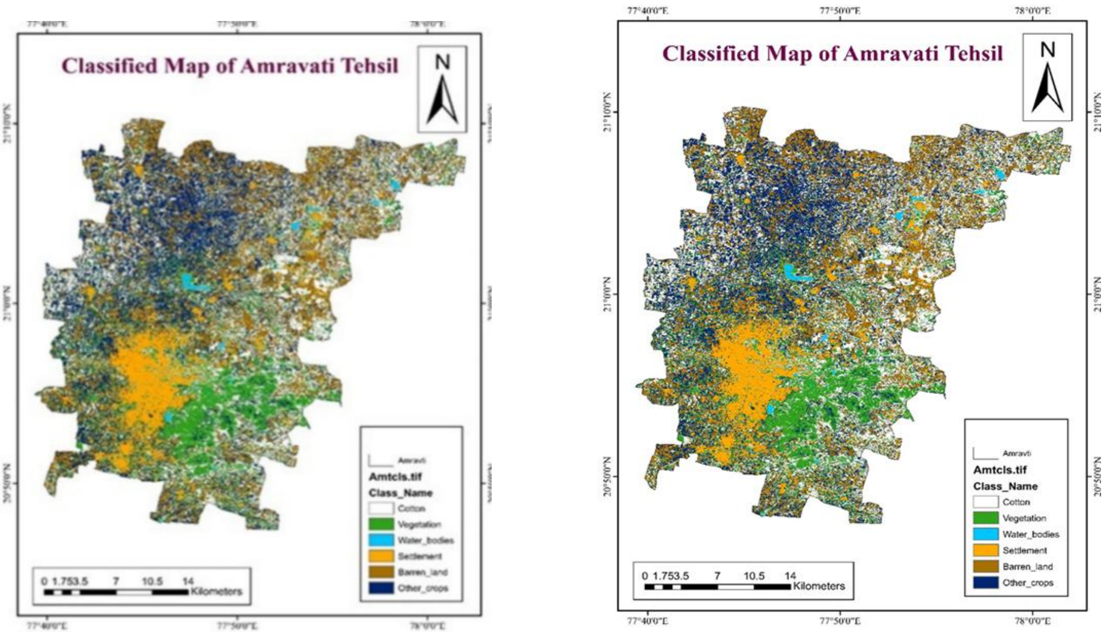

Figure 4. Classified Map of Study Area (2023-2024)

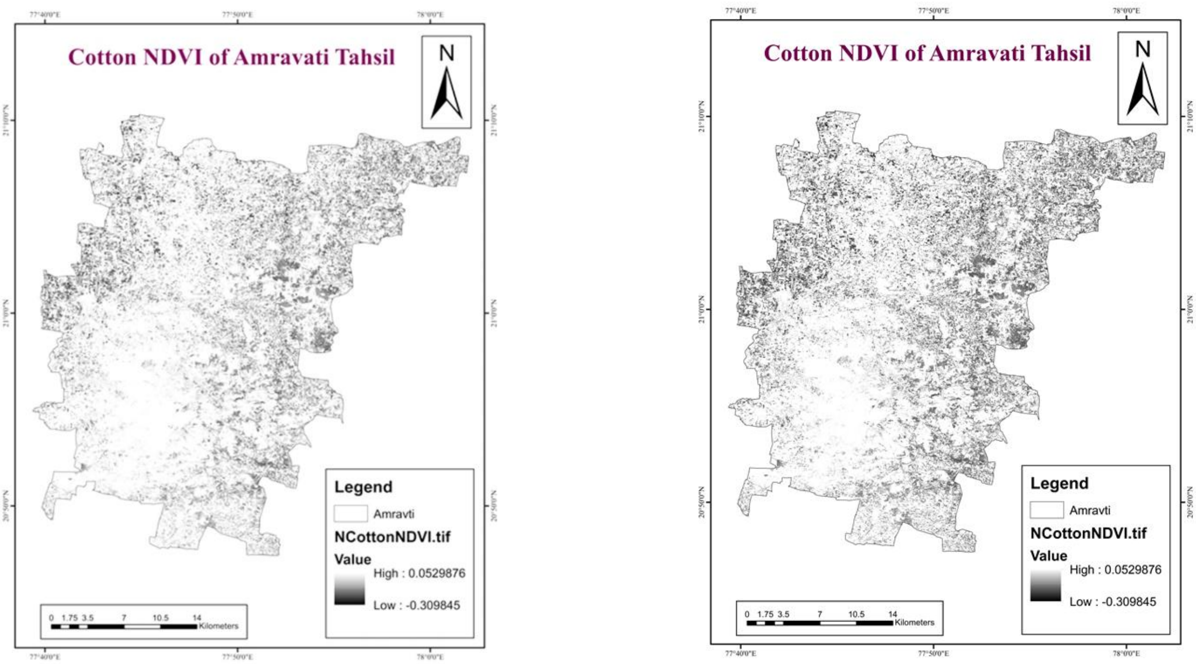

Figure 5. NDVI map of Study Area (2023-2024)

Comparative statement

The classification accuracy assessment of satellite imagery for cotton yield estimation across Amravati tehsil demonstrated noticeable improvements from 2023 to 2024. The overall accuracy for 2024 was higher across most classes, with Cotton improving from 87.5% to 90%, indicating better classification results and crop identification.

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Similarly, Producer Accuracy for Cotton increased significantly from 77.77% in 2023 to 88.88% in 2024, reflecting improved detection and consistency of cotton fields in 2024. Natural vegetation, water bodies, and settlement classes consistently showed 100% Producer Accuracy across both years. Meanwhile, Barren Lands and Other Crops classes also saw slight improvements in accuracy. (Figure 6).

These enhancements can be attributed to improved NDVI values in 2024, possibly due to favourable rainfall or better sowing practices, resulting in higher vegetation density and more distinguishable spectral signatures.

This comparative analysis reaffirms the reliability of remote sensing techniques and the crucial role of NDVI and ArcGIS in enhancing crop mapping and yield estimation processes.

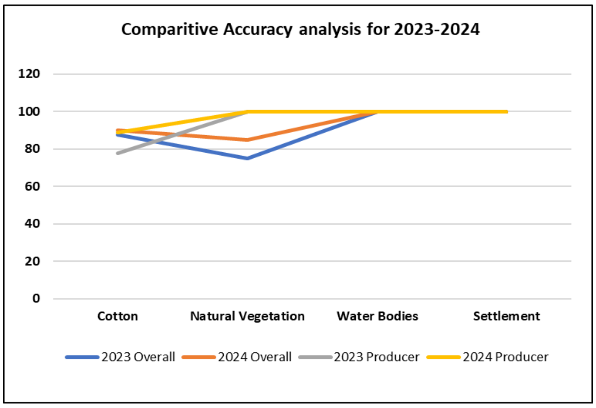

Figure 6. Comparative Accuracy analysis for cotton yield estimation across Amravati tehsil (2023-2024)

VII. CONCLUSION

As Agriculture is a vital component of a Nation's economy, so to leverage the agricultural practices to next level Remote Sensing Technologies can play crucial role in preventing crop damage and maintaining soil health by analysing yield and managing crop cultivation throughout the production process. This research reveals the minimum as well maximum possible yields of Cotton in Amravati Tehsil, highlighting the potential capabilities and reliability of combining ArcGIS, Google Earth Engine, USGS Earth Explorer and Google Earth Pro to accurately predict Cotton yields within the Tehsil. Leveraging software and tools like Google Earth Engine and USGS Earth Explorer allows us to acquire high-resolution satellite imagery, which is then processed using ArcGIS Software for our research objectives. This process generates NDVI and classified images, both of which are necessary for forecasting Cotton yields. In classification phase, we distinguish six classes: Cotton fields, Water bodies, Urban areas, Natural vegetation, Barren lands and Other crops. Moreover, the NDVI data offers crucial insights of vegetation density across Amravati Tehsil, enriching our understanding of agricultural conditions and helping us make more well-versed predictions. Integrating this information allows more accurate assessments of crop health and distribution as well, which is essential for effective agricultural planning and resource management.

The overall accuracy represents the total number of properly classified pixels out of total number of reference pixels, whereas the producer accuracy of our study indicates the accuracy of each of the six classified class categories. The Kappa accuracy of our research measures the perfection of classification process. These technologies have been proven to effectively support condition assessment, crop identification, area estimation, yield estimation, water management. The consequence of using yield estimation of crop through GIS technologies and Remote Sensing in agriculture lies in its ability to enhance farmer's decision-making capabilities, ultimately leading to improved crop management and increased productivity leading towards sustainable Agriculture. This study confirms that consistent methodology and improved data sources contribute to year-over-year accuracy improvements. NDVI and classification results show that cotton productivity in Amravati Tehsil was significantly higher in 2024 than in 2023. The outcomes support the use of satellite-driven GIS techniques for long-term agricultural planning.

REFERENCES

[1] A. Feng, J. Zhou, E. Vories, K. A. Sudduth and M. Zhang, "Yield estimation in cotton using UAV-based multi-sensor imagery," *Biosystems Engineering,* vol. 193, pp. 101-114, May 2020.

[2] J. Rodriguez-Sanchez, C. Li and A. H. Paterson , "Cotton Yield Estimation From Aerial Imagery Using Machine Learning Approaches," *Frontiers in Plant Science,* vol. 13, pp. 1-15, April 2022.

[3] L. Navi, Kushal, K. Gangadhar and S. Araga, "Yield prediction in field crops through satellite and," *The Pharma Innovation,* vol. 12, pp. 2431-2439, November 2023.

[4] Y. Huang, H. J. Brand, R. Sui, S. J. Thomson, T. Furukawa and M. W. Ebelhar, "Cotton Yield Estimation Using Very High-Resolution Digital Images Acquired With A Low-Cost Small Unmanned Aerial Vehicle," *Transactions of the American Society of Agricultural and Biological Engineers ,* vol. 59, no. 6, pp. 1563-1574 , 2016.

[5] M. A. Jabed and Masrah Azrifah Azmi Murad, "Crop yield prediction in agriculture: A comprehensive review of machine learning and deep learning approaches, with insights for future research and sustainability," *Heliyon,* vol. 10, no. 24, 2024.

[6] MSME Development Institute, 2012-2013. [Online]. [Accessed 2023].

[7] Murali, G. Krishna, Ramavenkata and M. N, "Optimizing Crop Yield Estimation through Geospatial Technology: A Comparative Analysis of a Semi-Physical Model, Crop Simulation, and Machine Learning Algorithms.," *AgriEngineering,* pp. 786-802, March 2024.

[8] Cropin, "NDVI and its Practical Applications in Agriculture," 17 December 2021. [Online]. Available: https://cropin.com/resource-blogs/ndvi-normalized-difference-vegetation-index/#:~:text=NDVI%20can%20also%20be%20used%20in%20precision%20agriculture%2C%20which%20is,field%20that%20need%20it%20most..

[9] R. G. Congalton, "A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of Environment," *Remote Sensing of Environment,* vol. 37, no. 1, pp. 35-46, July 1991.

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