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Trends in the Compound Annual Growth Rate of Mango Crop Area and Production

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ABSTRACT

Horticulture in Uttar Pradesh has become a popular livelihood, with fresh mango fruits influxing during harvesting season. The economic importance of mango production has increased due to domestic and international demand, fostering the use of waste and marginal lands, creating jobs, and implementing smart land-use practices. Governments department and concerned agencies can adjust their monetary strategies with the use of precise and timely details on the yield and acreage of mango orchards. This study estimates mango areas and production annually from 2014 to 2021 in four selected districts: Lucknow, Amroha, Bulandshar, and Meerut. The analysis reveals a maximum compound annual growth rate of 1.87% during the eight-year period (2013–2014 to 2020–21) in the mango acreage. It is also found that the Amroha district has shown an increasing growth rate in mango area during 2013-15 to 2019-21 but Lucknow, Bulandshar, and Meerut districts showed a decline in growth rate in mango area during 2013-15 to 2019-21. However, the Lucknow district showed the highest inter-annual fluctuation spanning the 2013–2014 to 2020–21 growing seasons for mangoes. The results of this study may be useful in policy decisions related to area expansion and increasing the production/productivity of the mango fruit crop.

Key words : Area estimation, Critical analysis, Image classification, Mango production, Landsat 8 OL

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INTRODUCTION

Horticultural crops have a special place in Indian economics, and accurate forecasts of the acreage devoted to these crops are crucial (Anonymous, 2016). Over time, both the mango growing region and its production have significantly risen. This has created several chances for the use of waste or marginal areas, the creation of jobs, and efficient land-use techniques (Verma *et al.*, 2020). The production of fruits and vegetables is a real source of income, employment, and citizen food security. (Jain and Choudhary 2021; Choudhary and Shekhawat 2022; Uddin *et al.* 2016). Horticulture crops were recognized by the Indian government as a way to diversify agriculture and increase profitability through effective land management, optimal utilization of the environment, water, soil as natural resources, and the creation of skilled rural jobs (Ibeawuchi *et al.* 2015). The potential for economic empowerment and job creation from these crops is very significant (Verma and Mishra, 2022). Increased output, productivity, and improved exports are the results of concentrated attention on horticulture research and development. The aforementioned initiatives have resulted in a substantial advancement in area expansion, which has increased productivity. Focused attention on horticulture research and development leads to increased output, productivity, and greater exports (Chennakrishnan, 2021). According to a study, the delayed introduction of better cultivars and the absence of better management techniques may be to blame for the lower growth rates of the chosen fruit crops. (Uddin *et al.*, 2016). In another study, Jha (2011) noted that agricultural growth caused by prices is not as significant as agricultural growth caused by technology. Besides, the use of modern technologies such as satellite image analysis has also led to rise in acreage and production. Many horticulture plants saw output increases of more than 50% between 1991–1992 and 1998–1999 (Ray and Kumar, 2011). The benefit of satellite images with optical sensors is that they can produce images of the Earth over a sizable portion of its surface, which is helpful for creating vegetation maps or estimating particular vegetation attributes. Another benefit is that it provides very good temporal resolution. Classification of optical satellite images plays a very important role in mango area monitoring as the very large area can be monitored in a short time and with minimum cost, so it provides cost-effective solutions. The world's longest-running, continuously-acquired collection of moderate-resolution satellite data is Landsat and it is the most commonly used optical satellite image for fruit crop monitoring and mapping (Verma *et al.* 2020).

The current techniques of estimating crop acreage mainly depend upon a sample survey method, which takes a lot of time for a large and diverse country like India. Modern space

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technology with cutting-edge satellite imaging technologies, geographic information systems (GIS), and GPS might also be used to estimate the acreage planted with horticultural crops. Since data spanning vast areas might be quickly obtained from such platforms, employing satellite data offers a synoptic picture as well as economies of scale. Planning horticulture development and management with geospatial tools is extremely quick, precise, and economical (Paul *et al.* 2018). Crop acreages are calculated using satellite images, and district-level acreage estimation uses stratified Knowledge-based Decision Tree classification of satellite images. By using ground-based observations of the study region, land-use/land-cover classes (LULC) are determined in this method, and spectral signatures for LULC classes are formed by using the gathered ground truth data. Multi-spectral satellite data has been employed in various instances for accurately measuring the area under crops and differentiating field crops (Verma and Dabas, 2011).

Using multispectral satellite data, this study aims to estimate the area and map the existing mango fruit crop orchards. Furthermore, the acreage data of the mango crop is critically analyzed by calculating the compound annual growth rate. Agriculture is unavoidably influenced by the weather, and crop acreage and productivity are subject to large fluctuations throughout time. The goal of this study is to estimate the acreage of mango crops by utilizing Landsat 8 OLI images from the four districts (i.e. Lucknow, Bulandshar, Meerut, and Amroha) of Uttar Pradesh state.

Following is the organization of the remainder of this paper. In Section – II, the region of interest and satellite images used are briefly described. The theoretical background of pre-processing of Landsat-8 images, indices used for mango area extraction and image classification using knowledge-based decision tree classification (DTC) technique. Trends in the compound annual growth rate (CAGR) of mango crop area and area estimation of mango crop areas are described in Section–III. After that, a critical analysis of mango crop areas for Meerut, Bulandshahr, Amroha, and Lucknow is provided in Section–IV. Section–V, gives a discussion of the results obtained from the proposed approach and a detailed analysis of the compound annual growth rate (CAGR) in the area under the mango crop. Finally, the concluding observations are given in Section VI.

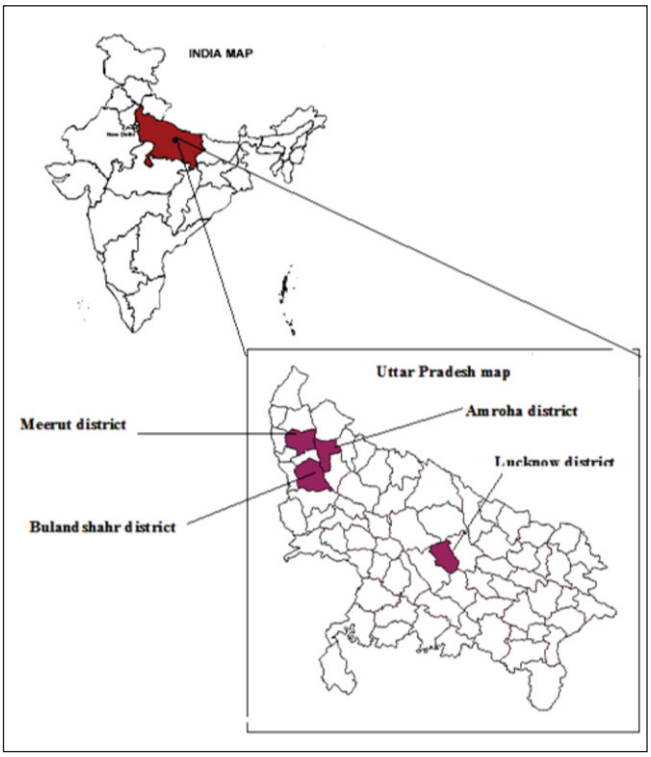


Fig. 1: Location Map of the study area.

Table 1: Details of LS 8 OLI images used for the study.

Acquisiti-on Date	Acquisition ID	Resolution (m)	Area of Interest
11-02-2014	LC08_L1TP_144041_20140211_20170425_01_T1	30	Lucknow
14-02-2015	LC08_L1TP_144041_20150214_20170413_01_T1	30	
17-02-2016	LC08_L1TP_144041_20160217_20170329_01_T1	30	
03-02-2017	LC08_L1TP_144041_20170203_20170215_01_T1	30	
10-03-2018	LC08_L1TP_144041_20180310_20180320_01_T1	30	
25-02-2019	LC08_L1TP_144041_20190225_20190309_01_T1	30	
12-02-2020	LC08_L1TP_144041_20200212_20200225_01_T1	30	
14-02-2021	LC08_L1TP_144041_20210214_20210304_01_T1	30	
09-02-2014	LC08_L1TP_146040_20140209_20180525_01_T1	30	Buland-s-hahr, Amroha and Meerut
12-02-2015	LC08_L1TP_146040_20150212_20170413_01_T1	30	
02-03-2016	LC08_L1TP_146040_20160302_20180524_01_T1	30	
05-03-2017	LC08_L1TP_146040_20170305_20170316_01_T1	30	
20-02-2018	LC08_L1TP_146040_20180220_20180308_01_T1	30	
23-02-2019	LC08_L1TP_146040_20190223_20190308_01_T1	30	
10-02-2020	LC08_L1TP_146040_20200210_20200224_01_T1	30	
28-02-2021	LC08_L1TP_146040_20210228_20210311_01_T1	30	

STUDY AREA AND DATA DESCRIPTION

Description of the study area

For this research, four major mango-producing districts are selected. These districts are Lucknow, Bulandshar, Meerut, and Amroha. Fig. 1 depicts the locations of all four districts.

The Lucknow district, which is nearly in the centre of India's Uttar Pradesh state, which is traversed by the Gomti river. The Lucknow district is situated between latitudes 26° 30' and 27° 10' N and longitudes 80° 34' and 81°12' E. It is renowned for its mango cv. Dashehari. The district of Bulandshahr is situated in the Meerut region of Uttar Pradesh (UP). The district is located between the latitudes of 28.4° and 28.0° N and the longitudes of 77.0° and 78.0° E. The district of Meerut is situated in the Indo-Gangetic plains of India between latitudes of 28°57' and 29°02' N and longitudes of 77°40' and 77°45' E. The boundaries of the Meerut region are the district of Bulandshahar in the south, the district of Muzaffarnagar in the north, and the districts of Ghaziabad and Baghpat in the west. The Ganges river serves as the district's eastern boundary, dividing it from Moradabad and Bijnor districts. The Amroha region is located between latitudes 28°54' and 39°6' north and 78°28' and 78°39' east.

Description of satellite data used

Landsat satellite images of Lucknow and Bulandshahr region for the period of 2014-21 were downloaded from the Earth Explorer web portal of USGS. Each Bulandshahr image includes the regions of Meerut and Amroha. Table 1 provides information about satellite images, including the date and Id of their capture as well as their spatial resolution.

MATERIALS AND METHODS

The main purpose of this research is to critically examine the growth and production of the mango fruit crop in Uttar Pradesh state's four key mango-growing regions: Lucknow, Bulandshahr, Meerut, and Amroha. The following steps have been used to analyze the growth and production of the mango fruit crop critically, which are as follows:

Pre-processing of Landsat -8 OLI images

The most crucial pre-processing procedures, according to Lu *et al.* (2004), are image registration, radiometric calibration, and atmospheric corrections. The Universal Transverse Mercator projection scheme (Zone: 44° N, Datum: WGS-84) is already *used to* georeference Landsat images. The radiometric calibration, or conversion of digital numbers into reflectance, is used as part of the pre-processing of the images, which span the districts of Lucknow, Bulandshahr, Meerut, and Amroha. To eliminate the atmospheric effect from these images, they have also undergone atmospheric correction.

Spectral indices used for mango fruit crop area classification

Three indices, such as normalized difference vegetation index (NDVI), modified normalized difference water index (MNDWI), and soil adjusted vegetation index (SAVI), which constitute a measure of the presence of a certain land feature are taken into consideration by utilizing the variation in reflectance properties after the Landsat-8 OLI images are pre-processed. The mathematical formulations to compute the NDVI, MNDWI, and SAVI indices are given in Equations (1), (2), and (3), and their details are given in (Ray and Kumar, 2011).

$$NDVI = \frac{(\rho_{NIR} - \rho_R)}{(\rho_{NIR} + \rho_R)} \quad (1)$$

Were, ρ_R is the Red band image and ρ_{NIR} is the Near Infrared (NIR) image (Ahmed and Singh, 2020).

$$MNDWI = \frac{(\rho_G - \rho_{SWIR1})}{(\rho_G + \rho_{SWIR1})} \quad (2)$$

where ρ_G is the Green band image and ρ_{SWIR} is the Short Wave Infrared-1 (SWIR1) image (Verma *et al.* 2020).

$$SAVI = \frac{(\rho_{NIR} - \rho_R) * (1 + L)}{(\rho_{NIR} + \rho_R + L)} \quad (3)$$

The value of L is taken as 0.5 to obtain the SAVI image (Verma *et al.* 2020).

By using the above three indices, knowledge-based decision tree classification has been applied on all four major mango-producing districts' images to critically analyze the mango fruit crop regions.

Images Classification by use of knowledge-based decision tree classifier

The knowledge-based decision tree classification model proposed in our previous study (Verma *et al.* 2020) is used to classify all three indices (i.e., NDVI, MNDWI, and SAVI) images derived from multitemporal Landsat 8 OLI images for (2014–2021) period of Lucknow, Bulandshahr, Meerut, and Amroha (Verma *et al.* 2020). The decision tree classification (DTC) model used for classification is shown in Fig. 2.

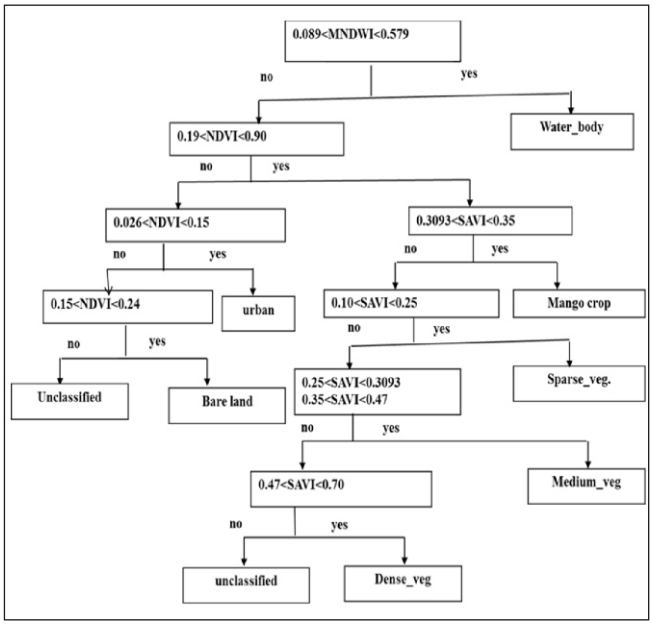


Fig. 2: Decision tree classification model (Verma *et al.* 2020).

This DTC model has been trained, thoroughly tested, and validated by using different sets of field data. Here, it is mentioned that the same DTC can be used effectively for the classification of different multi-temporal images even if atmospheric conditions might be slightly different. The reason is that all multi-temporal images are corrected by removing atmospheric effects during pre-processing of the raw images taken to conduct this critical study.

Indices images of all four districts are classified into the seven land cover classes: urban area, water body, mango crop, sparse vegetation, medium vegetation, dense vegetation, and bare land by applying the decision boundaries shown in Fig. 2. These classes are then used to estimate the total acreage of the mango crop in a given year.

Mango crop acreage estimation

Using classified images, the mango crop acreage is calculated, and the acreage estimation method is described in (Verma et al. 2020). In this paper, the Mango crop acreage has been calculated for all four districts for the period of 2014-21 by using Equation (4).

$$A_c = P_c * R * R / 100000 \quad (4)$$

Where P_c is the total number of pixels in mango crop class, R is the spatial resolution of the taken image i.e. 30 m, and A_c is the mango crop acreage obtained in hectare (ha).

Accuracy assessment

For the assessment of classification accuracies, a confusion matrix is derived by using classified images and ground truth data for urban, water, bare land, sparse vegetation, medium vegetation, mango crop area, and dense vegetation are the seven land cover classes. The confusion matrix is used to evaluate overall accuracy and the Kappa coefficient.

Trends in Compound Annual Growth Rate (CAGR) of mango crop area

The compound annual growth rate (CAGR)is a measure used to determine the growth rate throughout a number of years. It is a way to quantify a data series' continuous expansion. Compound growth rates are unaffected by volatility, in contrast to average growth rates which are susceptible to volatility levels. They are more comparable when comparing various data series. The area of mango crops in Uttar Pradesh's Lucknow, Bulandshahr, Meerut, and Amroha regions is the sole basis for the current study, which is completely based on time series data. The study period for the objectives is confined to a total duration of 8 years i.e. 2014-21. The mango crop area data are estimated by Landsat 8 OLI images. The period is visualized as a whole as well as by subdividing it into four periods as indicated below: Period – I: 2013-14 to 2014-15, Period – II: 2015-16 to 2016-17 Period – II: 2017-18 to 2018-19 and Period – IV: 2019-20 to 2020-21. The mathematical function to compute CAGR is given in Equation (5), which was used in several studies for the calculation of CAGR (Deb and Pramanik, 2015; Gairhe *et al*., 2018; Rimal and Gurung, 2016). In this paper, the compound annual growth rate (CAGR) in the acreage of the mango crop in all four districts is estimated by using Equation (5).

$$CAGR = \left(\frac{V_{final}}{V_{begin}} \right)^{1/t} - 1 \quad (5)$$

Where, CAGR = Compound Annual Growth Rate, V_{final} is the Final value, V_{begin} is the Beginning value, and t is Time in Years.

Implementation of decision tree classification for mango classification and area estimation

In this present work, the aim is to classify the satellite images of all four districts for the estimation of the mango area. For this purpose, all the steps shown in Fig. 3, are applied to multispectral Landsat 8 OLI images of 2014-21.

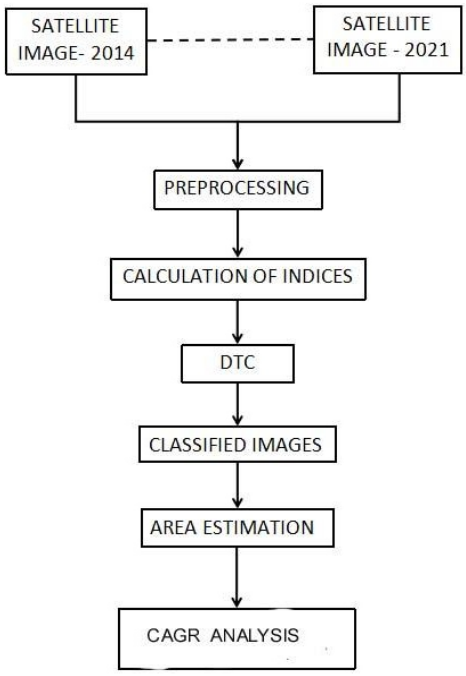


Fig. 3: Flow chart showing the steps of mango acreage estimation.

The first step is pre-processing of the satellite images. Out of the various pre-processing steps, the most important steps are- multi-temporal image registration, radiometric calibration, and atmospheric corrections (Verma and Dabas, 2011). Radiometric calibrations rectify pixel value inaccuracies and convert digital numbers to surface reflectance or radiance measurements. The next step involves using pre-processed images to create all three indices i.e. NDVI, MNDWI, and SAVI, where SAVI plays a major role in the classification of mango crops. Individual Bands (such as NIR and RED) images are shown to be ineffective at classifying the mango areas. As a result, images of the RED and NIR bands are used to derive the SAVI image. The images created as indices are then layer-stacked and classified using a knowledge-based decision tree proposed by the researchers (Verma et al., 2020) as the next step. Then, using field data, the accuracies (OA and KC) of the classification are determined. By using the steps mentioned in the flowchart shown in Fig. 2, mango crop areas are estimated for all four districts.

RESULTS AND DISCUSSION

Classification of Landsat 8 OLI images using knowledge-based decision tree

Eight years of Landsat 8 OLI images of commercial mango growing districts of Uttar Pradesh namely, Lucknow, Bulandshahr, Meerut, and Amroha are classified by using the knowledge-based decision tree classifier. District-wise classified images are given as follows:

Classification of Lucknow district images

Layer-stacked NDVI, MNDWI, and SAVI images of Lucknow district are classified using knowledge-based DTC mentioned in section 4. The classified images are shown in Fig.4(a)–4(h).

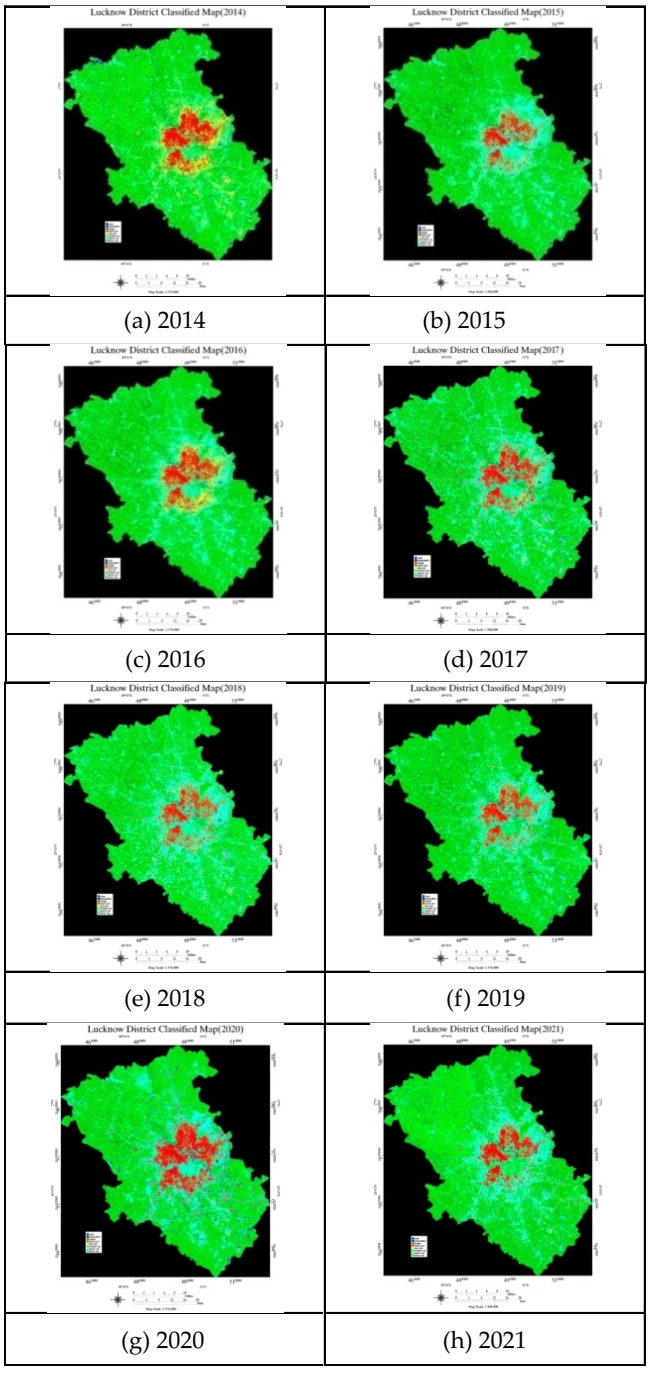


Fig. 4: Classified images of Lucknow district (2014-2021).

It has been noted that the area of the mango crop is 26.89 thousand ha in 2014-15 which has increased to 31.18 thousand ha in 2021 as shown in Table 3. Approximately 150 ground truth samples were collected and used to estimate the overall accuracy (OA) and Kappa coefficient (Kc). These two main accuracy assessment parameters are calculated using a confusion matrix. The values of OA and Kc for eight years (2014-21) of classified images are given in Table 2.

Table 2: Accuracy assessment of classified images of Lucknow.

Year	Lucknow	
	OA (%)	KC
2014	71.39	0.66
2015	86.69	0.83
2016	70.66	0.65
2017	75.51	0.70
2018	66.96	0.61
2019	68.42	0.63
2020	68.28	0.63
2021	86.13	0.83

From Table 2, it is found that the overall classification accuracy and Kappa coefficient for all the images (from 2014 to 2021) of the Lucknow region is pretty high, which suggests that classified images can be used to calculate the acreage of mango crops effectively.

Comparison between estimated mango crop area and reported area of Lucknow district

The production and area data for mangoes are obtained for analysis from the publications released by the Department of Agriculture, Cooperation and Farmers' Welfare, Government of India, with the title "Horticultural statistics at a glance for years 2013-14, 2014-15, 22015-16, 2016-17." For all four districts, area and production data were published by the Govt. till the year 2016-17.

In Table 3, the mango crop acreage, as determined by the classification of satellite images of the Lucknow district, is compared to the area and production figures published by the government for the years 2013–2014 to 2016–17. Using a linear regression model with production as the dependent variable and the satellite images-based calculated area as the independent variable, the production data are forecasted from 2017–18 to 2020–21. Similarly, the mango crop area from 1017-18 to 2020-21 is projected by using the moving average method. The projections for the production and crop area of mangoes were made using the same methodology for the four districts for the duration (2017-18 to 2020-21) and are mentioned as the reported area/production.

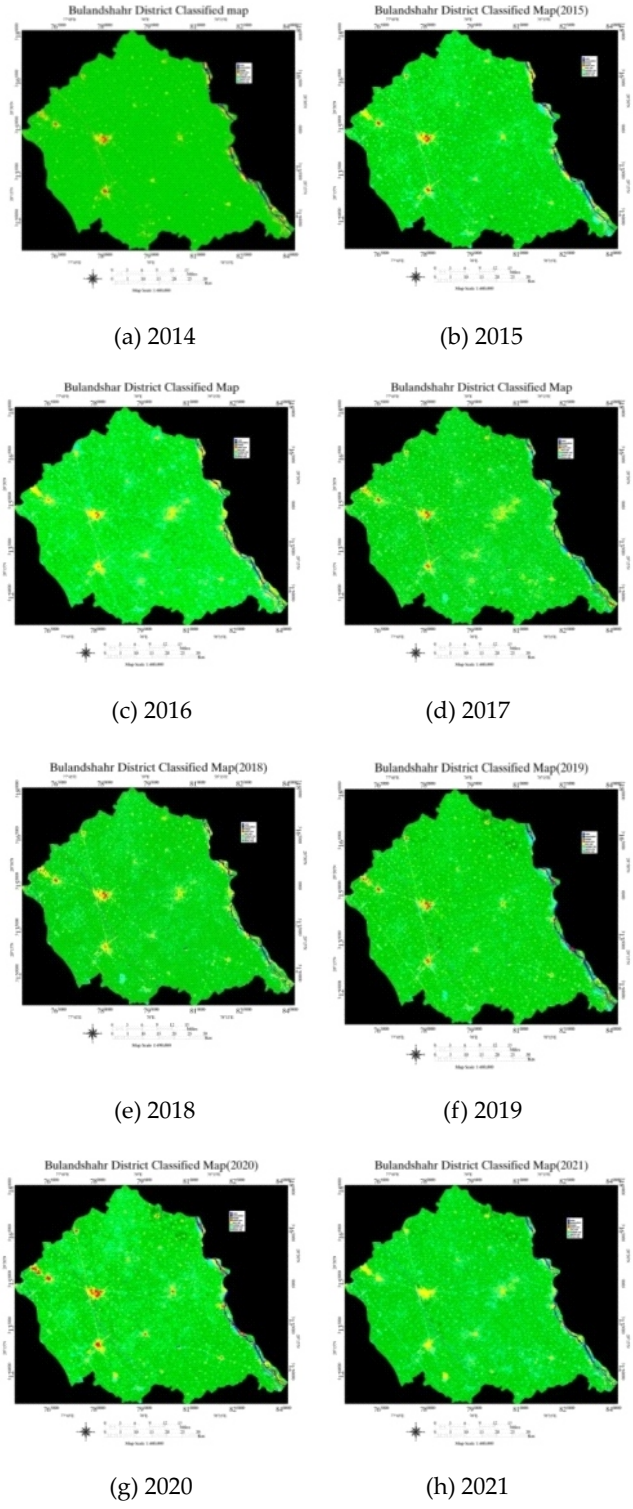
Table 3: Estimated area, reported area, and production of mango crop in Lucknow district during 2013-14 to 2020-21.

Year	Reported Area ('000 ha)	Estimated Area ('000 ha)	Production ('000 MT)
2013-14	28.05	26.89	524.59
2014-15	28.07	28.22	563.78
2015-16	29.47	29.41	585.2
2016-17	29.66	29.39	588.77
2017-18	29.07	29.7	595.513
2018-19	29.4	29.94	599.044
2019-20	29.38	30.86	620.803
2020-21	29.28	31.18	627.405

From Table 3, it is found that the mango acreage is increasing slightly each year but it decreased during the year 2017-18, which might be due to adverse weather conditions 2017-18.

Classified Images of Bulandshahr district

Layer-stacked NDVI, MNDWI, and SAVI images of the Bulandshahr district are classified using knowledge-based DTC shown in Fig. 2. The classified results are shown in Fig. 5 (a) - 5 (h).



(a) 2014 (b) 2015

(c) 2016 (d) 2017

(e) 2018 (f) 2019

(g) 2020 (h) 2021

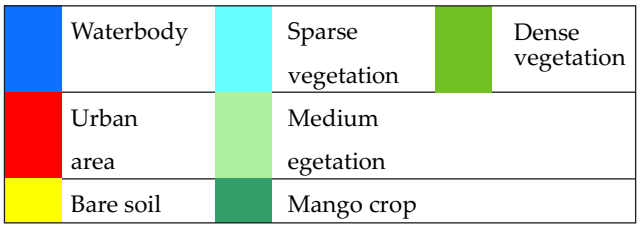


Fig. 5: Classified Images of Bulandshahrdistrict (2014-2021).

It is found that the mango acreage is 14.40 thousand ha in 2014-15 which increased to 16.09 thousand ha in 2020-2021. Possible causes of it may be favorable weather conditions and area expansions. A confusion matrix that was created using 135 ground truth samples was used to calculate the OA (%) and Kc. The values of OA and Kc for eight years (2014-21) of classified images are given in Table 4.

Table 4: Accuracy assessment of classified images of Bulandshahr district.

Year	Bulandshahr	
	OA (%)	KC
2014	67.71	0.61
2015	70.73	0.66
2016	65.84	0.61
2017	86.43	0.84
2018	75.63	0.71
2019	71.98	0.67
2020	69.61	0.63
2021	71.07	0.65

From Table 4, it is found that OA (%) varied from 65.84 to 86.46 and Kc varied from 0.61 to 0.84. If the Kc value is between 0.60 - 0.79 then classification is considered satisfactory. Higher the values of OA and Kc, the classification results are considered much better (McHugh, 2012). Therefore, it can be concluded that the classification accuracies of the images of different years of Bulandshahr district are good enough.

Comparison between estimated mango crop area and reported area of Bulandshahr district

Mango crops' approximate area as determined by the classification of satellite images of Bulandshahr district, and the area, as well as production reported by the government during different years from 2013-14 to 2020-21, are compared and shown in Table 5.

Table 5: Estimated area, reported area, and production of mango crop in Bulandshahr district during 2013-14 to 2020-21.

Year	Reported Area ('000 ha)	Estimated Area('000ha)	Production ('000 MT)
2013-14	14.49	14.40	234.40
2014-15	14.50	14.74	291.51
2015-16	15.22	15.16	261.48
2016-17	15.32	15.20	263.08
2017-18	15.01	15.46	275.29
2018-19	15.18	15.52	276.59
2019-20	15.17	15.9	284.82
2020-21	15.12	16.09	288.93

From Table 5, it is noted that the mango area is increasing slightly each year. Production has also increased with an increase in area in all periods except the year 2015-16.

Classified images of Meerut district

Layer-stacked NDVI, MNDWI, and SAVI images of the Meerut district are classified using knowledge-based DTC shown in Fig. 2. The classified maps are shown in Fig. 6(a)–6(h).

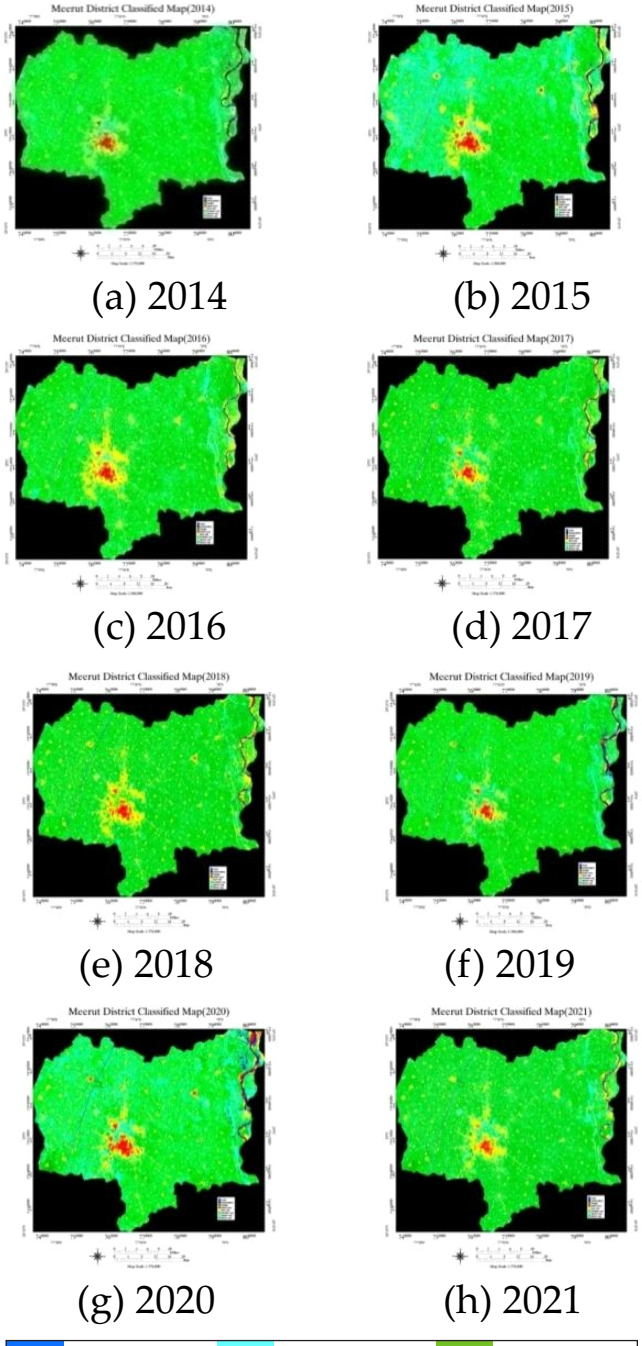


Fig. 6: Classified Images of Meerut District (2014-2021)

Using 165 ground truth samples from all classes, overall accuracy (OA) and Kappa coefficient (Kc) are calculated. The confusion matrix is derived by using the classified image and ground truth data; thereafter accuracy assessment parameters are calculated using the confusion matrix. The values of OA and Kc for eight years (2014-21) of classified images are given in Table 6.

Table 6: Accuracy assessment of classified images of Meerut

Year	Meerut	
	OA (%)	KC
2014	66.04	0.60
2015	66.99	0.61
2016	67.91	0.62
2017	82.84	0.78
2018	67.10	0.62
2019	66.14	0.60
2020	65.70	0.60
2021	68.58	0.63

Table 6 shows that all of the images of the Meerut district from 2014-2021 are classified with a very high OA ($\geq$ 65.70) and KC ($\geq$0.60), which implies that classified images could be effectively used to calculate the mango crop acreage. Using classified images, the government-reported and estimated areas of the mango crop in the Meerut district are compared.

Comparisons between estimated mango crop area and reported area of Meerut district

The mango crop acreage is calculated by classified images of the Meerut district, and the acreage and production of mango crops reported by the government are shown in Table 7.

Table 7: Estimated area, reported area, and production of mango crop in Meerut district during 2013-14 to 2020-21.

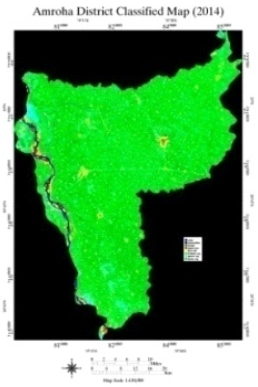
Year	Reported Area ('000 ha)	Estimated Area ('000ha)	Production ('000 MT)
2013-14	7.51	7.54	114.75
2014-15	7.63	7.97	123.32
2015-16	8.1	8.49	128.01
2016-17	8.4	8.65	128.79
2017-18	8.04	9.75	143.39
2018-19	8.18	8.27	125.05
2019-20	8.21	8.36	126.17
2020-21	8.14	8.74	130.88

The estimated and reported mango crop area and reported mango production of the Meerut district area have been plotted and shown in Table 7.

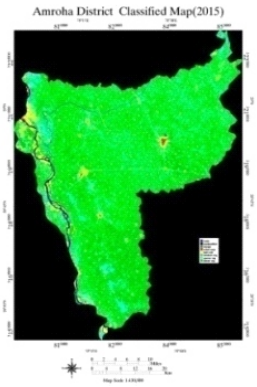
Table 7 shows that the acreage of mango crops fluctuates between 2013–14 and 2020–21. Along with local developments, production is shifting as well.

Classified images of Amroha district

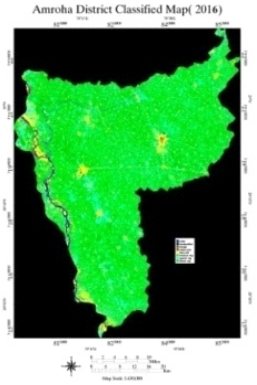
Layer-stacked NDVI, MNDWI, and SAVI images of the Amroha district are classified using knowledge-based DTC shown in Fig. 2. The classification results are shown in Fig. 7(a) -7(h).



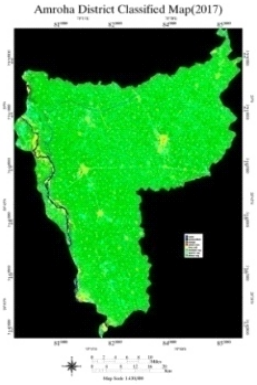
(a) 2014



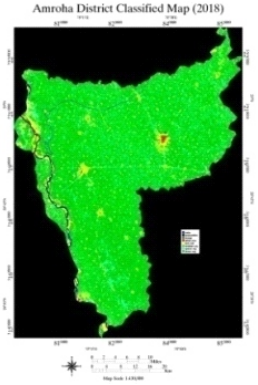
(b) 2015



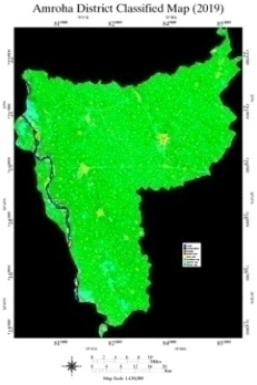
(c) 2016



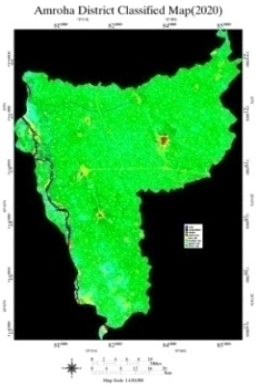
(d) 2017



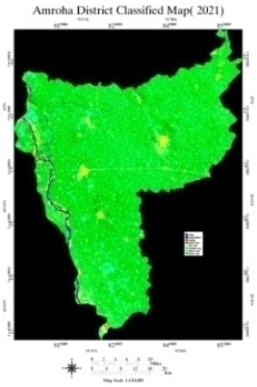
(e) 2018



(f) 2019



(g) 2020



(h) 2021

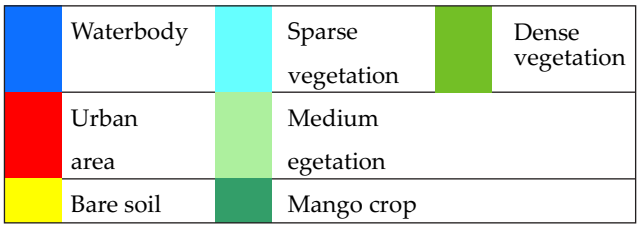


Fig. 7: Classified Images of Amroha District (2014-21)

The OA and Kc are estimated from a total of 110 ground truth samples. These two main accuracy assessment parameters are calculated using a confusion matrix. The values of OA and Kc for eight years (2014-21) of classified images are given in Table 8.

Table 8: Accuracy assessment of classified images of Amroha

Year	Amroha	
	OA (%)	KC
2014	81.00	0.78
2015	73.03	0.69
2016	68.94	0.64
2017	72.80	0.68
2018	65.68	0.60
2019	72.53	0.66
2020	66.88	0.61
2021	67.87	0.62

From Table 8, it is noted that the classified image of the years 2013-14 to 2020-21 resulted in a Kc value equal to or greater than 0.60. Therefore, it can be concluded that the classification accuracies of the images of different years of the Amroha district are good enough and acceptable for the estimation of crop area with better classification accuracies.

Comparison between estimated mango crop area and reported area of Amroha district

Table 9 displays the area of mango crops assessed through classified images of the Amroha district as well as the production and crop area reported by the government, and predicted using statistical methods, from 2013–2014 to 2020–21.

Table 9: Estimated area, reported area, and production of mango crop in Amroha district during 2013-14 to 2020-21.

Year	Reported Area ('000 ha)	Estimated Area ('000ha)	Production ('000 MT)
2013-14	8.8	8.79	175.96
2014-15	8.8	8.97	189.11
2015-16	9.24	9.45	196.29
2016-17	9.3	9.56	197.49
2017-18	9.11	8.2	165.142
2018-19	9.22	9.4	195.498
2019-20	9.21	9.5	197.118
2020-21	9.18	9.9	206.751

The estimated and reported mango crop area and reported mango production of the Amroha district area have been plotted and shown in Table 9.

From Table 9, it is observed that mango crop area has increased slightly during 2013-14 to 2016-17 and 2017-18-2020-21, respectively. Production has also increased with an increase in the area except 2020-21. For comparative analysis, all four-district data are plotted together by using year-wise estimated mango crop area as shown in Fig. 10.

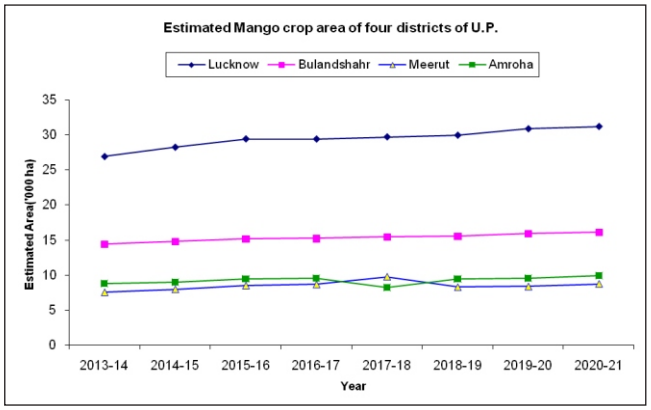


Fig. 8: Estimated mango area of four districts of Uttar Pradesh from (2014-15 to 2020-21).

From Fig. 8, it is observed that Lucknow district registered the highest mango crop area during 2014-21 among four districts and it is found that Meerut and Amroha districts registered maximum fluctuation in the mango crop area. It is also observed that Lucknow, Bulandshahr, Meerut, and Amroha districts have shown a marginal increase in mango crop area during (2014-21).

Compound Annual Growth Rate (CAGR) in the area under mango crop

The CAGR of mango crop area is calculated by using Equation (4) for five different time periods by using estimated mango crop area for four districts as shown in Table 10.

Table 10: Compound Annual Growth Rate (CAGR) in the Area of mango.

Period	Year	CAGR (%)			
		Lucknow	Bulandshahr	Meerut	Amroha
Period-I	2013-15	2.44	1.17	2.81	1.02
Period-II	2015-17	-0.03	0.13	0.94	0.58
Period-III	2017-19	0.40	0.19	-7.90	7.07
Period-IV	2019-21	0.52	0.60	2.25	2.08
Overall	2013-21	1.87	1.40	1.86	1.50

A perusal of the CAGR of mango crop area in Lucknow district indicated that the area under mango increased by 2.44% per annum during two years Period - I and then declined by -0.03% during Period - II and became negative as shown in Table 10. This negative growth has recovered to 0.40% per annum during the Period - III. Again CAGR shows a marginal increase of 0.52% per annum during the Period - IV. For an overall period, the growth rate is found to be 1.87% per annum. Similarly, in the Bulandshahr district, there is decreasing trend of growth rate from 1.17% to 0.13% and thereafter there are increasing trends from 0.13% to 0.19% and 0.60% between Periods II and III, and between Periods III and IV., respectively. For the overall period, CAGR is 1.40%. In the Meerut district, there is a decrease in the growth rate of 2.81% to 094% and 0.94% to -7.90% between Periods I and Period II, and Period II and Period III., respectively. Then an increase is observed in the magnitude of -7.90% to 2.25% from Period - III to Period - IV, respectively. For the overall period, CAGR is 1.86%. The CAGR of the mango crop area in Amroha district indicated that the area under mango increased by 1.04% per annum during two years i.e. period-I then declined to 0.58% during period - II. Thereafter, there is a big increase of 7.07% and a decrease to 2.88% during Period - III and Period - IV, respectively. In the overall period, the growth rate is 1.50%. The trends in the growth rate of all four districts of Uttar Pradesh are shown in Fig. 9.

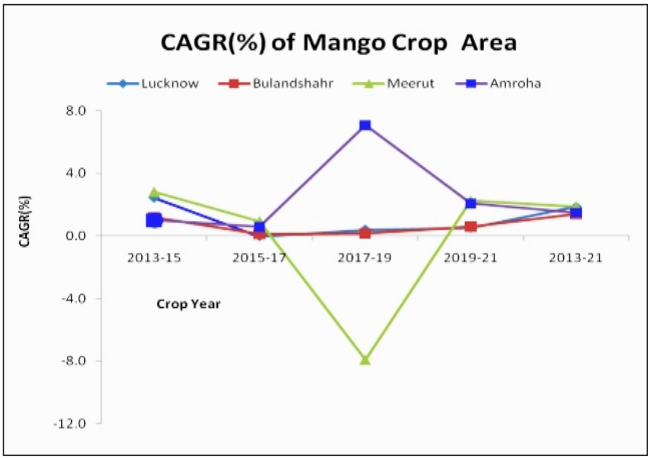


Fig. 9: Trends in Compound Annual Growth Rate (CAGR) in the area of mango crop.

From Fig. 9, it is observed that initially, a decreasing trend followed by an increase in all four districts except in Meerut is observed. Thereafter marginal decrease could be observed except Meerut and Bulandshahr districts. For the overall period, a positive growth rate could be seen for all districts. The findings will be beneficial in making policy decisions about area expansion and raising the yield and productivity of the mango fruit crop, especially in major mango-producing regions.

CONCLUSION

This study has shown significant promise to employ geospatial technologies and satellite images for horticultural development, particularly for infrastructure building and horticultural area expansion. It revealed the increasing trend of mango area and production in all four districts of Uttar Pradesh. An analysis of the trend in CAGR of mango crop area revealed that Lucknow district registered a maximum compound growth rate of 1.87% followed by Meerut district which registered CGAR of 1.86% during 8 years period (2013-14 to 2020-21). Also, different increasing/decreasing patterns of growth rate have been observed in mango crop areas for different districts. However, negative growth rates of -0.03% and -7.90% are recorded in the Lucknow district for the period 2015-17. Furthermore, an analysis of the estimated acreage of mango crops of 4 districts revealed that Lucknow district registered maximum fluctuation in the acreage of mango

crops. The results of this study are reliable and useful for policymakers/governments in area expansion planning.

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