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Spatial analysis of maize crop distribution in Telangana's deccan plateau using multi-temporal Landsat 8 data

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Abstract

This study focuses on mapping and delineating maize crop areas in eight districts of Telangana, India (Karimnagar, Jagtial, Peddapalli, Rajanna Siricilla, Jayashanker Bhupalpally, Medak, Sangareddy, and Siddipet), covering 19,263 km² in the Deccan Plateau Agro-climatic region. Utilizing Landsat 8 OLI and TIRS data from 2015-2017, maize areas were mapped for kharif (October-November) and rabi (November-February) seasons of 2016-17 using a hybrid approach involving NDVI and LSWI computations, isodata clustering, and decision rule classification. Ground truth data was collected via GPS, and image processing was performed using ERDAS Imagine 2016 and ARC GIS 10.8.1. Weather parameters, including temperature, rainfall, and radiation, were analyzed to contextualize crop conditions. Results showed a total maize area of 204,278 ha (kharif 2016) and 55,915 ha (rabi 2016-17), with deviations of 4.2% and 8.5% from observed data, respectively. Irrigated maize areas, delineated using three years of rabi data, totaled 516,926 ha, with a 6.2% deviation from observed data. The study highlights the efficacy of remote sensing in precise crop mapping and provides insights into spatial patterns of maize distribution and irrigation dynamics in Telangana.

Keywords: Remote sensing, maize, mapping, delineation, water limitation

Introduction

Maize (*Zea mays* L.) is a cornerstone of global agriculture, serving as a critical source of food, animal feed, and industrial products. In India, it ranks as the third most important cereal crop after rice and wheat, with significant cultivation in Telangana under rainfed (*kharif*) and irrigated (*rabi*) conditions. Precise mapping and delineation of maize areas are essential for optimizing agricultural planning, yield estimation, and sustainable resource management, particularly in regions with varied agro-climatic conditions (Thenkabail *et al.*, 2022) ^[12]. Traditional field-based surveys are often labor-intensive and limited in spatial scope, making them inadequate for large-scale crop monitoring. Remote sensing, particularly through platforms like Landsat 8 with its Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), provides moderate-resolution imagery (15-100 m) and a 16-day revisit cycle, enabling comprehensive crop monitoring. Spectral indices such as the Normalized Difference Vegetation Index (NDVI) and Land Surface Water Index (LSWI) facilitate the differentiation of crop types and water regimes, crucial for mapping rainfed and irrigated areas to enhance agricultural productivity and water use efficiency.

Recent advancements in remote sensing underscore its efficacy for crop mapping. Thenkabail *et al.* (2021) ^[11] emphasize the role of multi-temporal satellite data in global cropland monitoring, while Kumar *et al.* (2023) ^[8] demonstrate the integration of Sentinel-2 and Landsat data for crop-type classification in India. Zhang *et al.* (2024) ^[15] highlight the use of NDVI and LSWI for distinguishing irrigated and rainfed agriculture. Additionally, Gumma *et al.* (2022) ^[5] showcase machine learning with Landsat data for maize and rice mapping in South Asia, and Li *et al.* (2023) ^[9] explore multi-sensor data fusion for enhanced crop delineation. Recent studies by Wang *et al.* (2024) ^[14] and Patel *et al.* (2025) ^[10] further advance the application of deep learning and high-resolution imagery for precise crop monitoring, while Chen *et al.* (2023) ^[2] illustrate

the integration of remote sensing with ground-based data for improved accuracy in agricultural mapping. This study focuses on mapping maize crops across eight Telangana districts (Karimnagar, Jagtial, Peddapalli, Rajanna Siricilla, Jayashanker Bhupalpally, Medak, Sangareddy, and Siddipet), spanning 19,263 km² in the Deccan Plateau Agro-climatic region. Using Landsat 8 data from 2015-2017, a hybrid approach integrating NDVI, LSWI, isodata clustering, and decision rule classification was employed to delineate maize areas during *kharif* (rainfed) and *rabi* (irrigated) seasons of 2016-17. These methodologies align with the current study's approach, which incorporates ground truth GPS data and weather parameters to ensure robust analysis of maize distribution and irrigation patterns, providing

valuable insights for agricultural policy and resource management.

Materials and Methods

Description of Study Area

The study area selected was erstwhile Karimnagar and Medak districts of Telangana, currently covering eight districts viz., Karimnagar, Jagtial, Peddapalli, Rajanna Siricilla, Jayashanker Bhupalpally, Medak, Sangareddy and Siddipet falling in the Deccan Plateau Agro-climatic region of India (Figure 1). Geographically it is located between 17°0.76'N to 18°0.83'N latitudes and 77°0.87'E to 79°0.46'E longitudes. It covers an area of approximately 19,263 km².

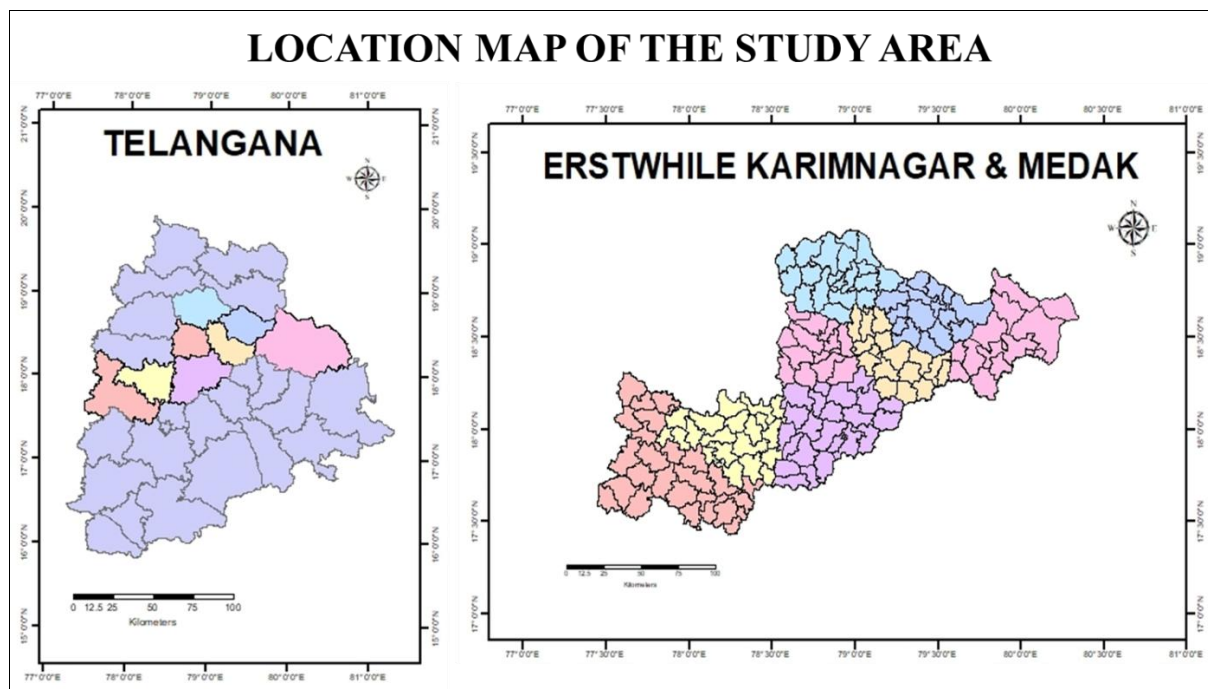


Fig 1: Location map of the study area

Landsat 8 is an U.S Earth Observation satellite launched on February 11, 2013, from Vandenberg Air Force Base, California, on an Atlas-V 401 rocket with extended payload fairing from United Launch Alliance. Originally called the Landsat Data Continuity Mission (LDCM), it is collaboration between NASA and United States Geological Survey. The Landsat 8 satellite consists of two sensor instruments. Those are Operational Land Imagery (OLI) and Thermal Infrared Sensor (TIRS). Landsat 8 satellite can provide global data with an interval of 16 days with spatial resolution of 15 meter (panchromatic), 30 meter (visible, NIR, SWIR), 100 meter (thermal). Temporal and radiometric resolution of 16 days and 12 bits with swath width of 185 km. Landsat 8 data available with free of cost. Landsat 8 provides moderate resolution imagery from 15 meter to 100 meters of Earth's land surface and polar region. Landsat 8 sensors capture nearly 400 scenes per day and sensors have improved signal to noise (SNR) ratio and good radio metric performance. Remote sensing data is the basic data source for mapping the crop of the selected regions. The

Landsat 8 OLI data of 2015, 2016 and 2017 imageries were used for studying maize crop. The collateral data used are toposheets, boundary of erstwhile Karimnagar and Medak districts, crop statistics at district and block level from Department of Agriculture and ground truth data in the form of GPS points.

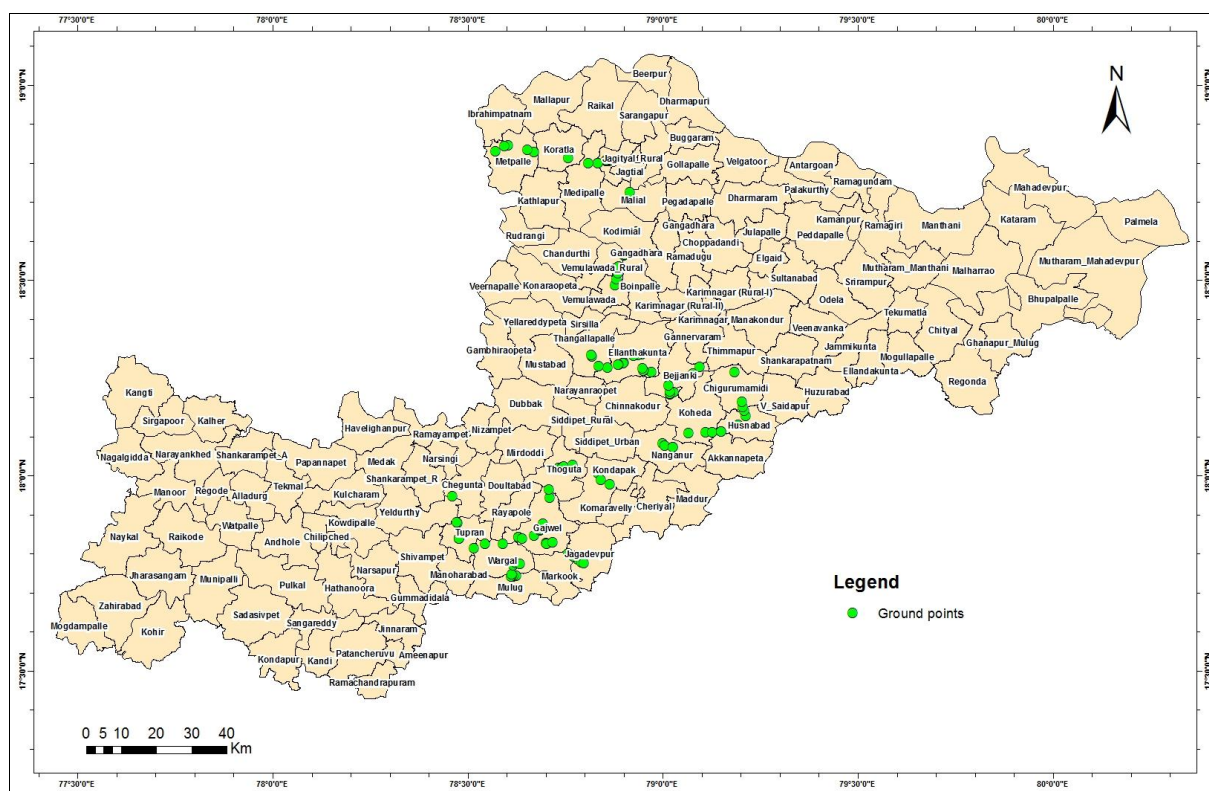
Landsat 8 operates in different range of frequencies. Each range of frequencies is called spectral band. Landsat 8 has 11 spectral band (visible, NIR, SWIR, thermal bands) (Table 1). The GARMIN, GPS 72H GPS receiver in stand-alone mode in Fasal FDC application was used to collect the information regarding the geographical co-ordinates, soil type, crop type, stage of the crop and crop photo of the field points sites for the present investigation (Figure 2 and Table 2). ERADAS Imagine 2016 software was used for importing, image geo-referencing and rectification for studying crop changes. It also played a key role in preparing models and for classifying the satellite image. ARC GIS 10.8.1 was used for map composition and MS office was used for database preparation.

Table 1: The satellite data used for studying maize crop during *kharif*, 2016 and *rabi*, 2016-17

Season	Satellite	Sensor	Path/ orbit	Row/ sector	Date of Acquisition
<i>Kharif</i>	Landsat 8	Operational Land Imager (OLI)	143	47	23.10.2016, 08.11.2016, 24.11.2016
			143	48	
			144	47	14.10.2016, 30.10.2016, 15.11.2016
			144	48	
<i>Rabi</i>	Landsat 8	Operational Land Imager (OLI)	143	47	10.12.2016, 26.12.2016, 11.01.2017, 12.02.2017, 28.02.2017
			143	48	
			144	47	17.12.2016, 02.01.2017, 18.01.2017, 03.02.2017, 19.02.2017
			144	48	

Table 2: Information on Ground truth field observation

Period	2016-17 (<i>Kharif</i> & <i>Rabi</i>)	Date of field visit	21.09.2016 & 22.09.2016 (<i>Kharif</i>), 02.02.2017 (<i>rabi</i>)
Mobile App used	Bhuvan Fasal App	Area	26 Mandals
Crops covered	Maize, Cotton, Paddy, Redgram	No. of observations	104
Parameters collected	Geographical co-ordinates, Crop type, Stage of the crop, Soil type, Condition of the soils and Crop photo of the field points sites		

**Fig 2:** Map showing ground truth field observation points

For studying maize crop, the cloud free data of Landsat 8 for the *kharif* and *rabi* seasons were downloaded from USGS Earth Explorer, NASA <http://earthexplorer.usgs.gov> in TIFF format. The green, red and near infrared wavelengths representing bands 2, 3, 4, 5, 6 and 7 of Landsat 8 were layer stacked together followed by mosaicking where the four tiles (143/47, 143/48, 144/47 and 144/48) were added to get mosaic image, later masked with 20m resolution agrimask of Telangana (Sentinel data), hence generated a subset for the area of interest as primary data analysis using district shape file. The information in the false colour composite was not related to the real world. Hence geometric correction was performed through georeferencing, which established the relation between row/column numbers and real world coordinates using UTM projection with WGS-84 spheroid datum (Table 3). Thus, all the data sets were brought to a common projection. This ensured the satellite imagery to have a spatial reference with the real world.

Table 3: Spectral band specifications of Landsat 8 OLI/TIR

Band Number	Band Name	Band width (μm)	Resolution
Band 1	Coastal	0.433-0.453	30 m
Band 2	Blue	0.450-0.515	30 m
Band 3	Green	0.525-0.600	30 m
Band 4	Red	0.630-0.680	30 m
Band 5	NIR	0.845-0.885	30 m
Band 6	SWIR1	1.560-1.660	30 m
Band 7	SWIR2	2.100-2.300	30 m
Band 8	Pan	0.500-0.680	15 m
Band 9	Cirrus	1.360-1.390	30 m
Band 10	TIRS1	10.6-11.2	100 m
Band 11	TIRS2	11.5-12.5	100 m

Mapping and delineation of maize area

Delineation of maize crop in the study area, a hybrid approach was followed using 15 days OLI optical data (Landsat 8) for the year 2016-17. For mapping *kharif* and *rabi* maize temporal

datasets from October to November and November to February period respectively were processed and NDVI was computed using stacked NDVI images for the defined period. NDVI measures the distinction between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). The stacked NDVI was masked with potential agricultural area and it is followed by isodata clustering generating 100 classes and 25 iterations. These clusters are labeled as maize / other classes based on field data points using decision rule approach. Decision rule was based on the maize crop profile based on top profile of maize crop in that area. The maize area delineated with remote sensing was compared with the observed data obtained from Area and Production Statistics, 2016-17.

Mapping and delineation of maize Irrigated and rainfed area

Three years data was used to delineate the potential irrigated zone in the study area. For this purpose we have emphasized on *rabi* season where the effect of rainfall on the crop was nullified. Irrigated zones were delineated based on assumptions of healthy maize crop (higher NDVI) represents irrigated area. Hence for delineating potential irrigated area the temporal datasets OLI (15 days composite) was processed during the period (October to February) for three years (2015-18). NDVI computed for respective image and stacked seasonal NDVI and LSWI were created. NDVI indicates measure of the amount and vigor of vegetation while, LSWI is sensitive to the total amount of liquid

water in the crop thus widely used to monitor moisture stress. These stacked NDVI and LSWI layer was masked with potential agricultural area. For mapping irrigated maize again hybrid approach was followed. Isodata clustering was carried out by giving 100 classes and 25 iterations then followed by a decision rule classification. Decision rule was developed based on the ground observation where irrigated maize crop was assured to be associated tagged with higher NDVI and LSWI throughout *rabi* season. The same step methodology was repeated for three years to generate three irrigated zones separately. To generate potential irrigated map union operation of three years datasets was carried out. The irrigated area delineated with remote sensing was compared with the observed data obtained from Area and Production Statistics, 2016-17.

False color composite (2, 3 and 4 bands) was generated for the *kharif* 2016 and *rabi* 2016-17 from to demarcate the agricultural area from non-agricultural area by following steps *viz.*, layerstack, mosaicking and extraction of the area of interest.

Results and Discussion

Weather Information of the Study Area

The study area comprised Karimnagar, Jagtial, Peddapalle, Rajanna Siricilla, Jayashanker Bhupalpally, Medak, Siddipet, Sangareddy districts. The weather parameters *viz.*, rainfall, maximum and minimum temperature were observed during the crop growing period. The detailed weather prevailed during *kharif* 2016 at eight districts are illustrated in Figures 3 and 4.

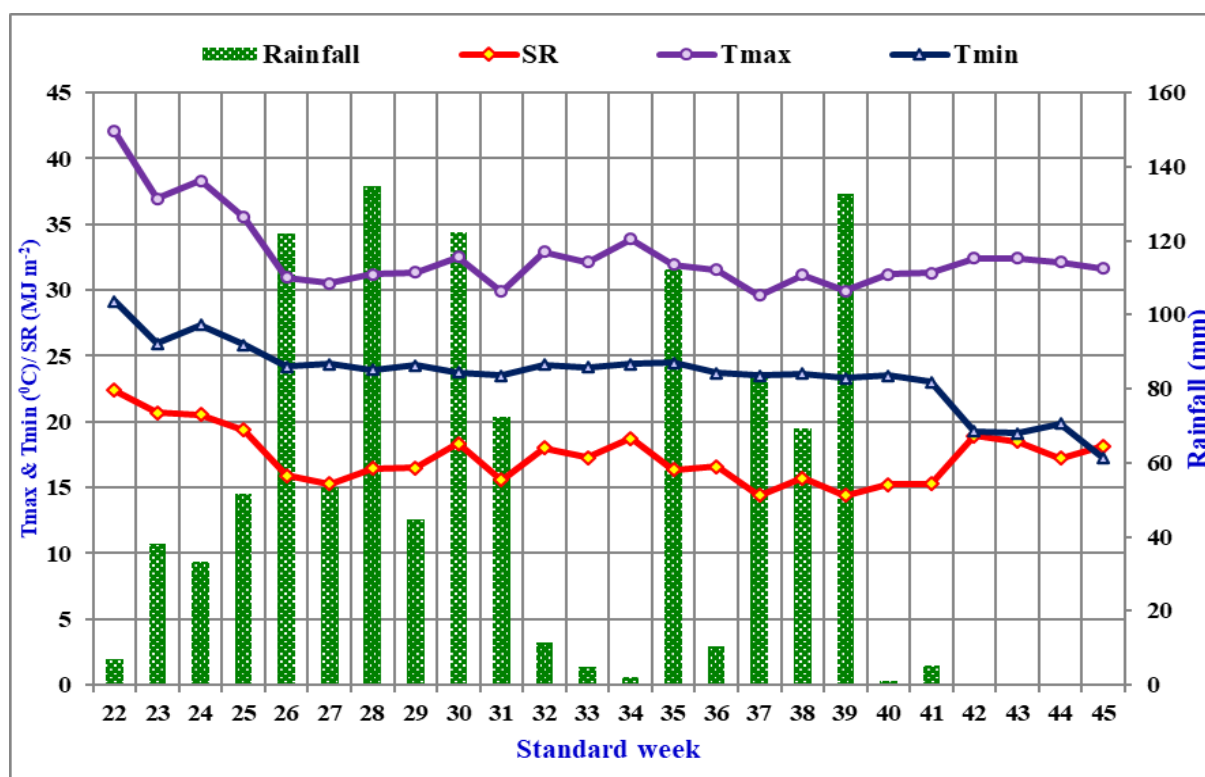


Fig 3: Weather prevailed in erstwhile Karimnagar during *kharif* 2016

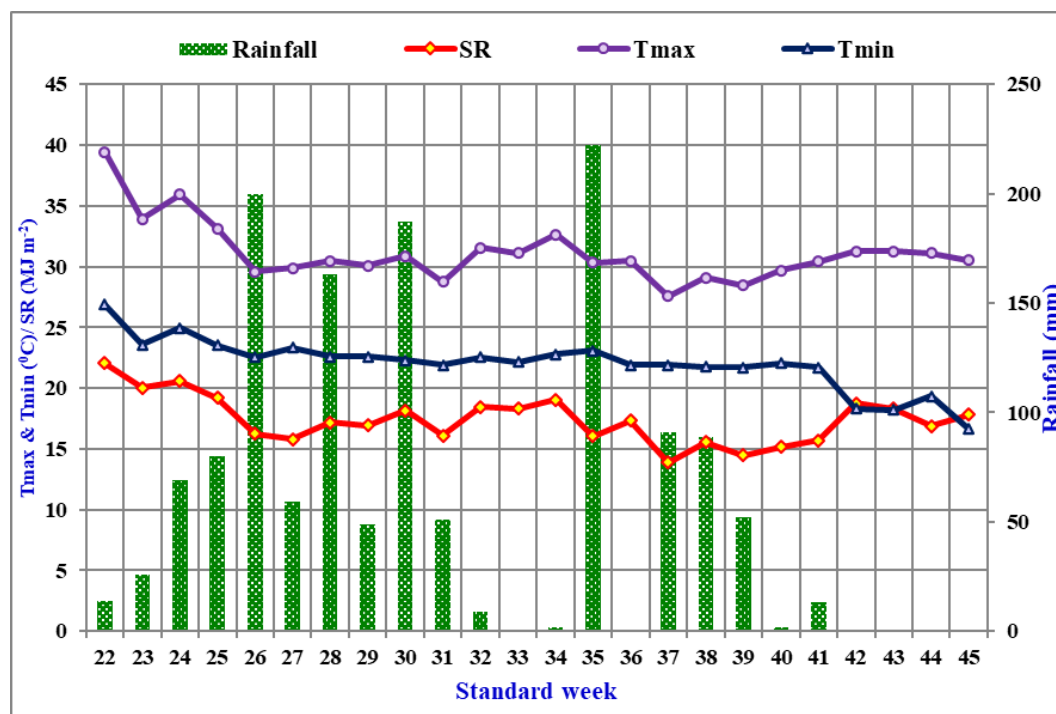


Fig 4: Weather prevailed in erstwhile Medak during *kharif* 2016

During *kharif* 2016, the weekly mean maximum temperature at Karimnagar and Medak districts ranged from 29.6 to 42.1°C with a mean of 32.6 and 27.6 to 39.4°C with a mean of 31.2°C, respectively. The weekly mean minimum temperature varied between 17.2 to 29.2°C with an average of 23.6°C in Karimnagar and 16.6 to 26.9°C with an average of 22.0°C in Medak. During *kharif* 2016, 1112.6 and 1378.0 mm of rainfall was recorded at erstwhile Karimnagar and Medak districts, respectively. The weekly mean radiation varied between 15.2 and 22.4 MJ m⁻² day⁻¹ with an average of 17.3 MJ m⁻² day⁻¹ in Karimnagar and 13.9 to 22.1 MJ m⁻² day⁻¹ with an average of 17.4 MJ m⁻² day⁻¹ in Medak.

The weather condition prevailed during *rabi* 2016-17 at

erstwhile Karimnagar and Medak districts are illustrated in Figures 5 and 6. During *rabi* 2016-17, the mean weekly maximum temperature ranged from 30.4 to 37.7°C with an average of 32.9 in Karimnagar and 29.1 to 36.9°C with an average of 32.1°C in Medak, respectively. Whereas, the weekly mean minimum temperature varied between 12.9 to 20.8°C with a mean of 17.2°C in Karimnagar and 14.4 to 20.3°C with a mean of 17.3°C in Medak. During *kharif* 2016, 42.3 and 48.0 mm of rainfall was recorded at erstwhile Karimnagar and Medak districts, respectively. The weekly mean radiation varied between 16.6 and 23.7 MJ m⁻² day⁻¹ with an average of 19.2 MJ m⁻² day⁻¹ in Karimnagar and 15.0 to 23.4 MJ m⁻² day⁻¹ with an average of 18.7 MJ m⁻² day⁻¹ in Medak.

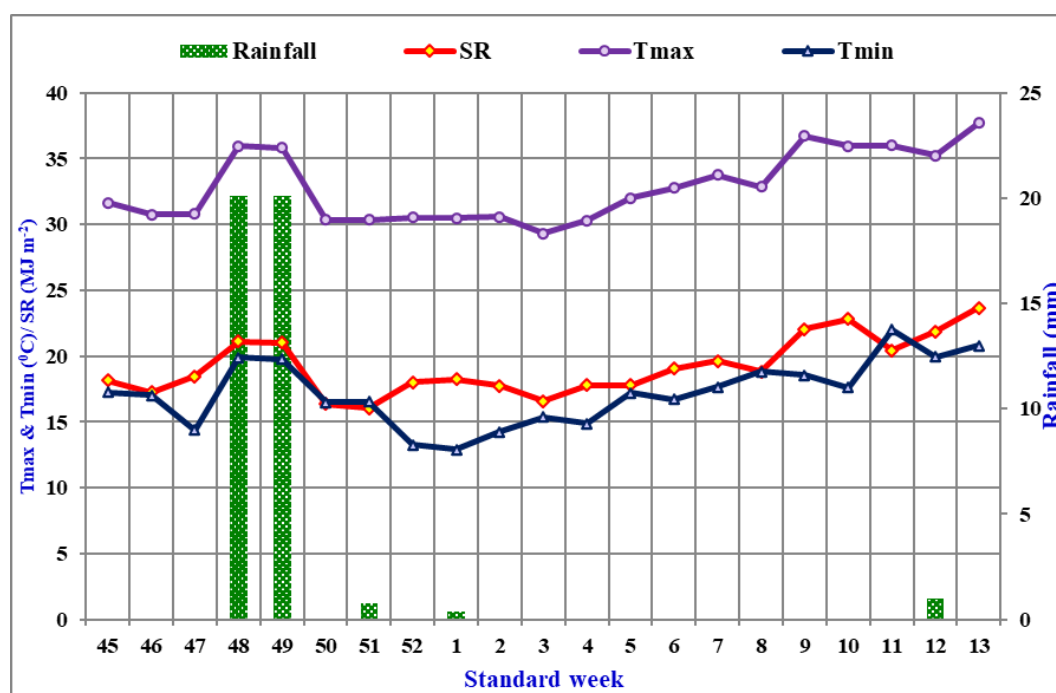


Fig 5: Weather prevailed in erstwhile Karimnagar during *rabi* 2016-17

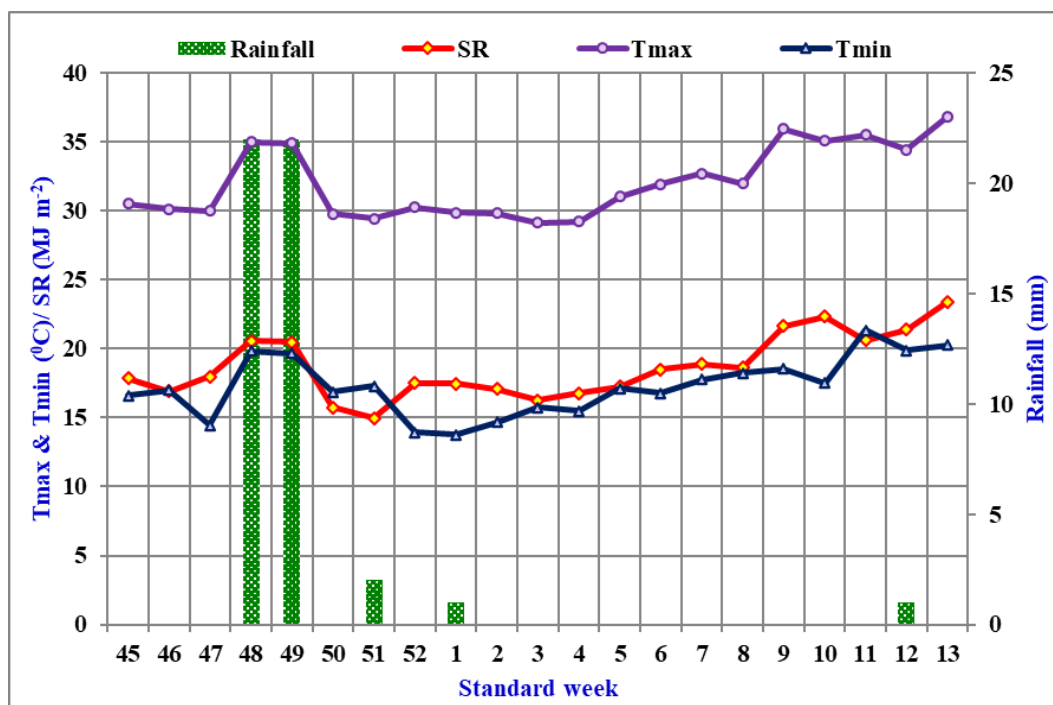


Fig 6: Weather prevailed in erstwhile Medak during *rabi* 2016-17

Spatial Patterns of Maize Crop Distribution

Maize area map was extracted for the study area covering districts *viz.*, Karimnagar, Jagtial, Peddapalli, Rajanna Siricilla, Jayashanker Bhupalpally, Medak, Siddipet, Sangareddy districts from Landsat 8 OLI images. District and mandal wise maps and statistics of maize area were estimated for 141 mandals of eight districts using the shapefiles with administrative boundaries. The accuracy assessment for the maize area maps was conducted on a maize / non-maize basis, where all other land cover types were grouped into a single non-maize class. A total, 104 points covering 63 maize and 41 non-maize points were used for

validation in eight districts.

The summary of district wise maize area is given in Tables 4 and 5 and the classified maize area across erstwhile Karimnagar and Medak districts was 60,138 ha and 1,53,188 ha, respectively in *kharif* 2016. These two districts cumulatively accounted for 2,13,326 ha during the season under rainfed condition. During *rabi* 2016-17, the maize area was also estimated using remote sensing techniques and found to be 35,799 ha and 25,322 ha, respectively in Karimnagar and Medak districts with a total of 61,121 ha.

Table 4: District wise maize area during *kharif* 2016 in the study area

<i>Kharif</i> 2016	Observed Area (ha)	Mapped area (ha)	% deviation
Jagtial	24,948	21,027	-15.7
Karimnagar	18,643	20,396	9.4
Peddapalli	8,065	8,371	3.8
Rajanna Siricilla	5,592	7,672	37.2
Jayashanker Bhupalpally	2,890	2,393	-17.2
Total (Erstwhile Karimnagar)	60,138	59,859	-0.5
Medak	31,345	35,996	14.8
Sangareddy	20,462	27,287	33.4
Siddipet	1,01,381	81,136	-20.0
Total (Erstwhile Medak)	1,53,188	1,44,419	-5.7
Grand total	2,13,326	2,04,278	-4.2

Table 5: District wise maize area during *rabi* 2016-17 in the study area

<i>Rabi</i> 2016-17	Observed Area (ha)	Mapped area (ha)	% deviation
Jagtial	11,270	10,140	-10.0
Karimnagar	16,234	13,638	-16.0
Peddapalli	4,490	4,965	10.6
Rajanna Siricilla	1,013	1,197	18.2
Jayashanker Bhupalpally	2,792	3,266	17.0
Total (Erstwhile Karimnagar)	35,799	32,206	-10.0
Medak	9,931	8,580	-13.6
Sangareddy	2,051	3,057	49.0
Siddipet	13,340	11,072	-17.0
Total (Erstwhile Medak)	25,322	23,709	-6.4
Grand total	61,121	55,915	-8.5

Maize Area during Kharif 2016

Among the eight districts monitored for maize area during *kharif* 2016 (Table 4), Siddipet recorded the large, homogeneous and landscape dominating maize area of 1,01,381 ha as against the mapped area (81,136 ha) with -20% deviation followed by Medak and Jagtial registering an area of 31,345 and 24,948 ha respectively. Sangareddy and Karimnagar were

the next best districts recording maize areas of 20,462 ha and 18,643 ha. Jayashanker Bhupalpally followed by Rajanna Siricilla, Peddapalli recorded the lowest maize area of 2,890, 5,592 and 8,065 ha, respectively. The mapped area also followed the same trend as the observed area. Maize area maps during *kharif* 2016 covering the study area are depicted in Figure 7.

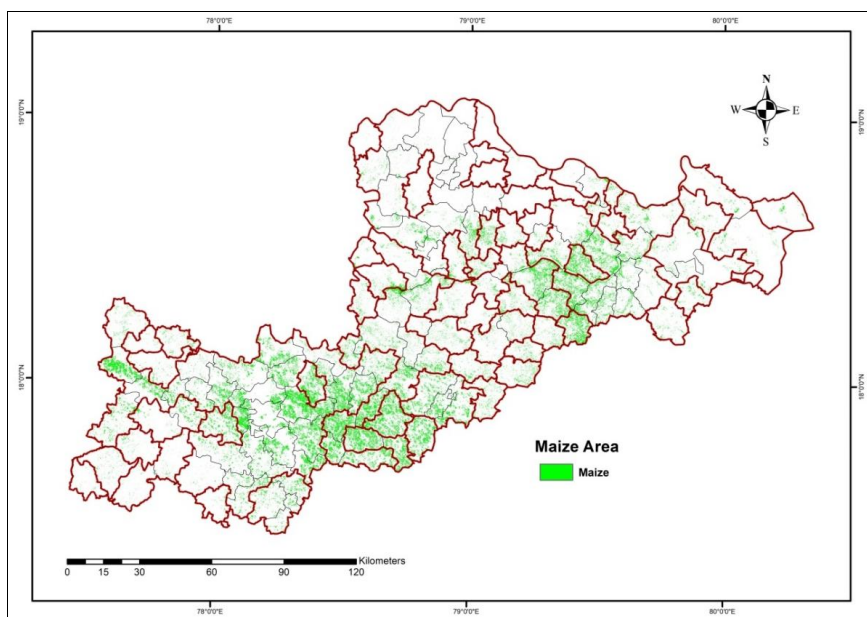


Fig 7: Satellite data derived maize crop area map for the study area during *kharif* 2016

Data showed that a good agreement between observed and mapped maize area and the lowest deviations ranged from 3.8 and to 9.4% was observed in Peddapalli and Karimnagar districts among all eight districts mapped. However, the observed maize area (2,13,326 ha) was lower by 4.2% compared to the total area mapped (2,04,278 ha).

Maize Area during Rabi 2016-17

Among the eight districts monitored for maize area during *rabi* 2016-17 (Table 5), Karimnagar recorded the maize

area of 16,234 ha as against the mapped area 11,072 ha with deviation of -16.0%, followed by Siddipet and Jagtial registered an area of 13,340 ha and 11,270 ha respectively. Medak and Peddapalli have recorded maize areas of 9,931 ha and 4,490 ha. Rajanna Siricilla, Sangareddy and Jayashanker Bhupalpally districts recorded the lowest area of maize 1,013; 2,051 and 2,792 ha, respectively. The mapped area also followed the same trend as the observed area. Maize area maps during *rabi* 2016-17 covering the study area are depicted in Figure 8.

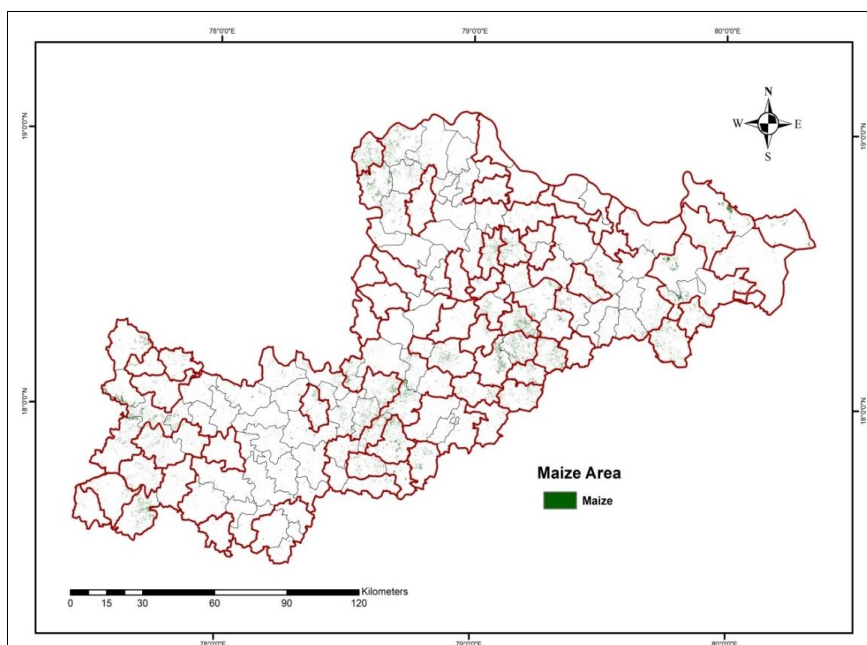


Fig 8: Satellite data derived maize crop area map for the study area during *rabi* 2016-17

Data showed a good agreement between observed and mapped maize area with the lowest deviations ranged from -10.0 and -10.6% was observed in Jagtial and Peddapalli districts among districts mapped. However, the observed maize area (61,121 ha) was lower by 8.5% compared to the total area mapped (55,915 ha). The short-term variations of sown areas show a high temporal variation over recent decades in the Hyderabad, with 41 to 58% of sown areas in *kharif* and 8 to 22% in *rabi* between 2005 and 2016 (Ferrant *et al.*, 2017) [3].

Irrigated Area Mapping

Under irrigation during *rabi* (Table 6) Jagtial district showed the

normal maize area of 93,859 ha as against the mapped area 1,02,082 ha with a deviation of 8.8% followed by Karimnagar and Siddipet registered an area of 81,188 against 77,569 ha and 74,257 against 83,146 ha with deviations of -4.5 and 12%, respectively. Peddapalli and Medak were the next best districts recorded a normal area 67,188 as against 75,655 ha and 59,275 ha as against 62,459 ha with the deviation of 12.6% and 5.4%, respectively. Rajanna Siricilla (38,342 ha) followed by Sangareddy (38,138 ha) and Jayashanker Bhupalpally (34,344 ha) recorded the lowest normal maize area, respectively. Irrigated area maps covering the study area are depicted in Figure 9.

Table 6: District wise irrigated area in the study area

<i>Rabi</i> 2016-17	Normal Area (ha)	Mapped area (ha)	% deviation
Jagtial	93,859	1,02,082	8.8
Karimnagar	81,188	77,569	-4.5
Peddapalli	67,188	75,655	12.6
Rajanna Siricilla	38,342	39,208	2.3
Jayashanker Bhupalpally	34,344	43,567	26.9
Total (Erstwhile Karimnagar)	3,14,921	3,38,081	7.4
Medak	59,275	62,459	5.4
Sangareddy	38,138	33,240	-12.8
Siddipet	74,257	83,146	12.0
Total (Erstwhile Medak)	1,71,670	1,78,845	4.2
Grand total	4,86,591	5,16,926	6.2

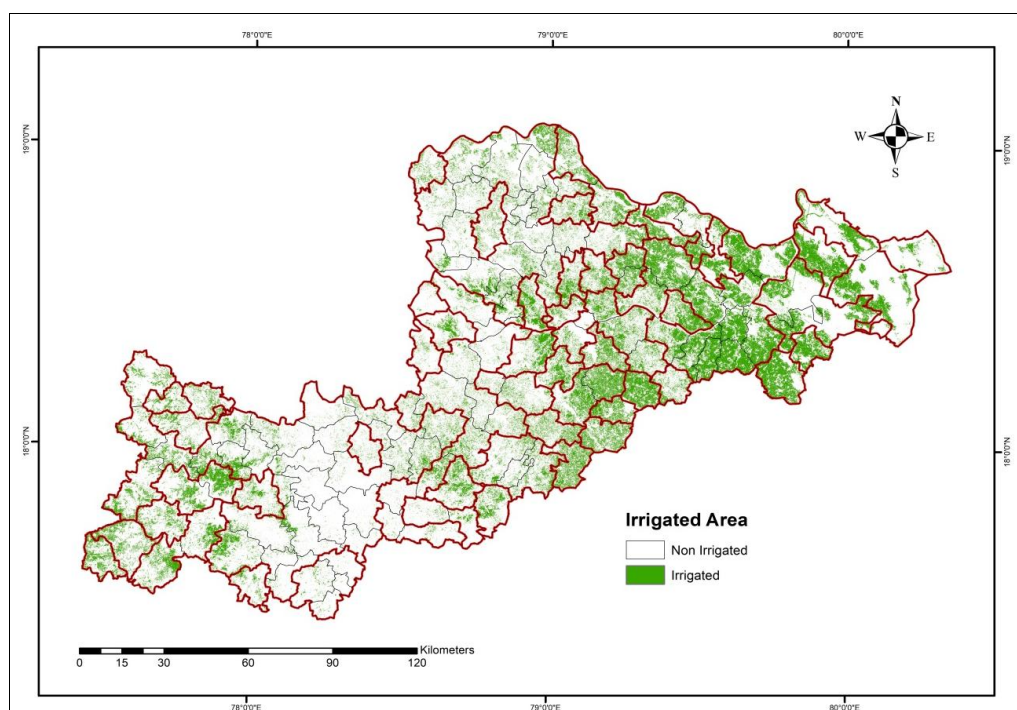


Fig 9: Satellite data derived irrigated area map of the study area

Data showed that a good agreement between normal and irrigated area mapped. The lowest deviations ranged from 2.3 - 4.5% was in Rajanna Siricilla and Karimnagar districts. However, the total irrigated area (4,86,591 ha) was lower by 6.2% compared to the total area mapped (5,16,926 ha). Census of India, the irrigated area varies between 15-17%. Large changes in land cover over a small time interval of 10 years was seen in the statistics of different studies are not possible and thus are attributed to other causes. Irrigated areas in two remote sensing applications were 35 and 16%, respectively at crop mapping of Malaprabha, Karnataka (Heller *et al.*, 2012) [6]. Kumar *et al.* (2015) [7] found areas under paddy and cotton were

39 and 29% respectively in mapped crop areas in the Fatehabad district of Haryana. Recent studies, Velpuri *et al.* (2021) [13], Thenkabail *et al.* (2022) [12] and Zhang *et al.* (2024) [15], highlighted the efficacy of NDVI and LSWI in distinguishing irrigated from rainfed crops, while Abuzar *et al.* (2023) [1] and Gao *et al.* (2024) [4] emphasize multi-sensor data fusion and machine learning for precise irrigation mapping. These methodologies align with the current study's approach, reinforcing the reliability of remote sensing for irrigated area delineation and its potential for informing water management strategies.

Conclusion

The study successfully mapped maize crop areas across eight Telangana districts using Landsat 8 data, demonstrating the effectiveness of remote sensing techniques in agricultural monitoring. The hybrid approach, integrating NDVI and LSWI with isodata clustering and decision rule classification, accurately delineated maize and irrigated areas, with deviations ranging from 3.8-20% for maize and 2.3-12.6% for irrigated zones compared to observed data. Siddipet and Karimnagar emerged as key maize-producing districts, with significant areas under both rainfed (*kharif*) and irrigated (*rabi*) conditions. Weather data underscored the influence of climatic factors on crop growth, with distinct temperature and rainfall patterns across seasons. The methodology ensured robust spatial alignment through geo-referencing and UTM projection, enhancing the reliability of the maps. These findings provide valuable data for agricultural planning and policy-making in Telangana, with potential applications in other agro-climatic regions for crop monitoring and resource management.

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