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Application of geospatial technique in identification of cropping pattern and cropping intensity in central Gujarat, India

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Abstract

The agricultural sector in India has gone through several changes with increasing population and infrastructural development in the last few decades. Cropping pattern and cropping intensity are two important aspects of agriculture. The spatial pattern of these aspects varies over space and time with the changing determining factors. Identification of the changing nature of these agricultural aspects in a timely manner with considerable accuracy is not only the need of the time but also necessary for the future. The application of geospatial techniques is elementary in this context. The present study, was restricted to the analysis of the cropping pattern and cropping intensity with the help of geospatial technique in the central Gujarat region of India, covers an area of 2941 sq. km of area. IRS Resourcesat-2A LISS-III satellite images of 2015-16 were used in the study. Band rationing technique namely Enhanced Vegetation Index (EVI 2) was adopted to detect cropping patterns of different seasons. Further from the cropping pattern, the crop combination was prepared. In this study, the result showed that EVI 2 method is very much suitable for the identification of cropping pattern and cropping intensity with better accuracy. It was also found that salinity is controlling both the cropping pattern and cropping intensity in the presented area.

Keywords: *cropping pattern, cropping intensity, band rationing, EVI2.*

Introduction

From primitive subsistence agriculture to present day market oriented advanced commercial farming; the agricultural sector has gone through a positive change throughout the world in general and in India in specific. Looking at the past few decades, India showed a positive escalation in different crops as population growth was the major driving force in association with the green revolution. Cropping pattern, productivity and intensity are the three major yardsticks for the quantification of agricultural output. Hence, to understand the development in the agricultural sector, timely quantification of growth parameters is critical. Natural factors like temperature, precipitation, physiography, soil etc. and anthropogenic factors like demand, the market economy, use of fertilizers and pesticides etc. definitely have an impact on these aspects. The cropping pattern in India varies over a year as different crops are grown in June-July to October–November (Kharif), October–November to February–March (Rabi), January–February to April–May (Zaid). In this context, cropping pattern as well as cropping intensity varies over space. Different scholars have tried to address the cropping pattern and cropping intensity and have given probable solutions. For the identification of cropping pattern and cropping intensity satellite based vegetation indices like NDVI, EVI, EVI2, NDSBVI, dNDVI etc. are very important methods (Jiang et al. 2019, Mondal et al. 2014, Vyas et al. 2013, Panigrahy et al. 2010). Ray et al. (2005) evaluated the cropping pattern and crop rotation cropping system using Multiple Cropping Index (MCI), Area Diversity Index (DI) and Cultivated Land Utilization Index (CLUI). For the mapping of cropping pattern and crop rotation, researchers have used several satellite images, Multi-date IRS LISS I, IRS WiFS sensor (Panigrahy et al. 2004), SPOT VEGETATION (VGT) (Panigrahy et al. 2010), IRS Resourcesat-2 LISS-III (Mondal et al. 2014), MODIS data, China's Environment Satellite (HJ-1) (Hu et al. 2018), INSAT 3A CCD (Vyas et al.2013), Landsat ETM+ as well as IKONOS satellite images (Husak et al. 2008) was used.

From different studies, it is clear that, not only for the present but also for the purpose of future food security, closer observation of the agricultural practices of any region is essential with superior accuracy. In the present paper, an attempt has been made to depict the cropping pattern of the central part of Gujarat by using the band rationing technique viz. Enhanced Vegetation Index (EVI 2). Further, cropping intensity is also depicted from the result.

Study Area

The study area is located in the central part of Gujarat state and adjoins the Gulf of Khambat. It extends between 72°15'-73°18' east longitude and 22°07' – 23°29' north latitude (CGWB, 2016). It largely incorporates much of the present Anand district of Gujarat. The geographical area of the region is 2941 km^2 (CGWB, 2016). It is bordered by Vadodara district in the east, Gulf of Khambat and Bharuch district in the south, Ahmedabad district is on the west and Kheda district is towards the north (Fig. 1).

The study area is divided into three major physiographic units viz. piedmont plain, alluvial plain and coastal plain. Piedmont plain spreads over 15-20 km towards the north-east of the region. The relief of the zone is between 70-80 meters (CGWB, 2016) (Fig. 2). Most of the area is covered by alluvial plain. The height of the zone is 15-20 meters above the mean sea level. Medium and shallow black soils are largely found in the entire study area. Mahi and Sabarmati are the two major rivers in this region. The mean maximum temperature ranges between 28.4°C during January to about 41.8°C during May and the mean minimum temperatures vary between 11.7°C during January and 27°C during June. Rainfall is largely received from the south-west monsoon between June and September (Chinchorkar et al. 2015).

Central Gujarat is one of the richest agricultural belts of Gujarat (CGWB, 2016). On the other hand, a large part of the region is under the coastal plain, mainly in the south-west (Tarpur and Khambat talukas). In this zone, the soil is also saline (CGWB, 2016).

Methodology

The present study was based on multi-spectral and multi-temporal satellite images of Resourcesat 2A LISS-III. Three satellite images of 8th October 2015 (Kharif), 12th January 2016 (Rabi) and 17thApril-2016 (Zaid) were used for the entire study. Actual cropland data for three seasons were

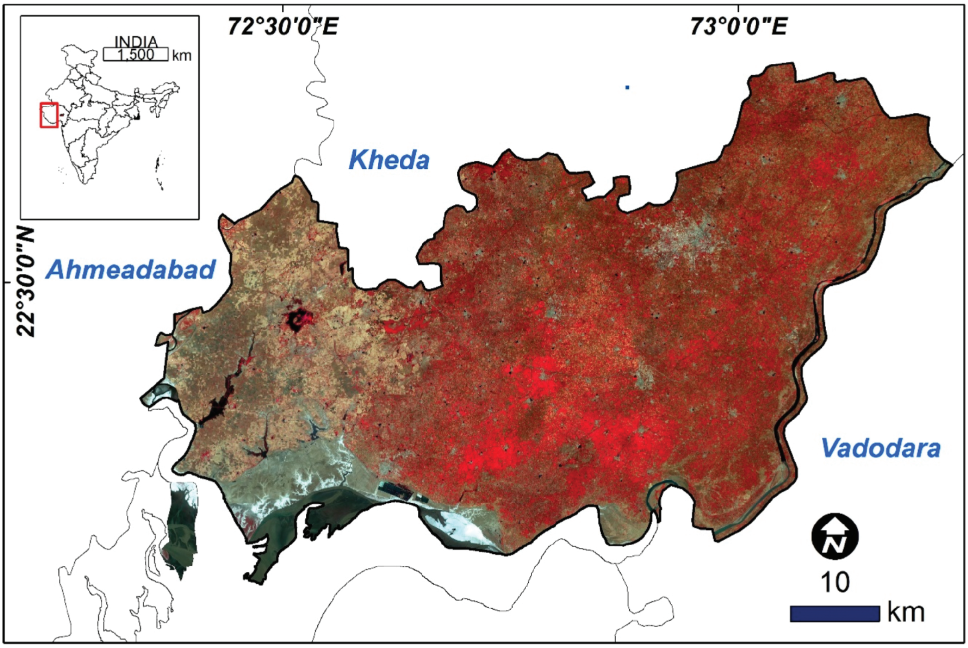

Fig:1 Location Map

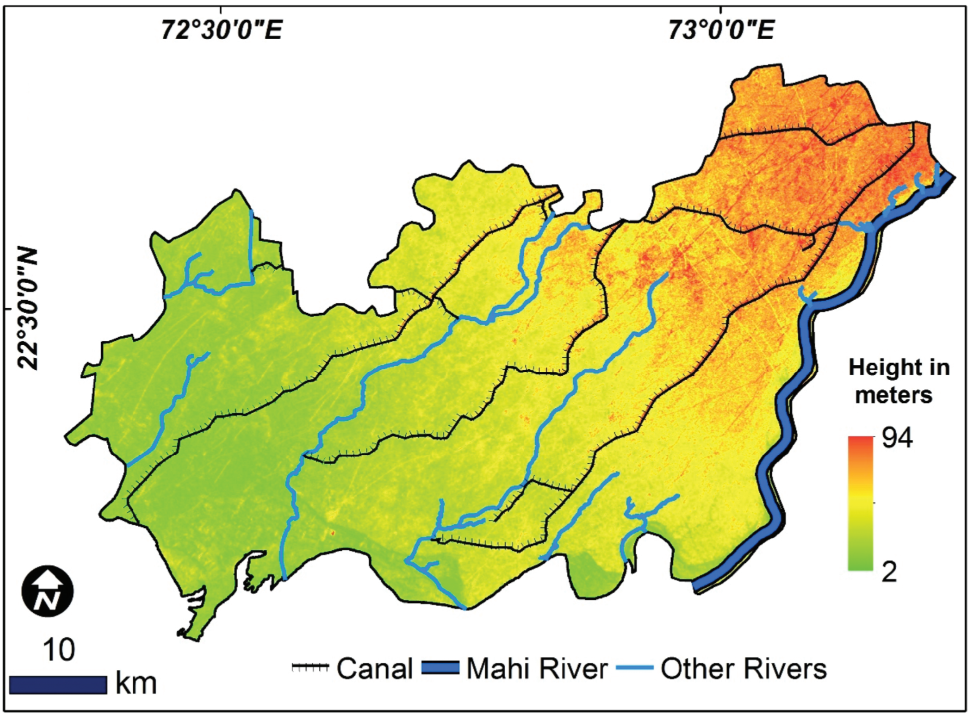

Fig:2 Elevation Model with River and Canals

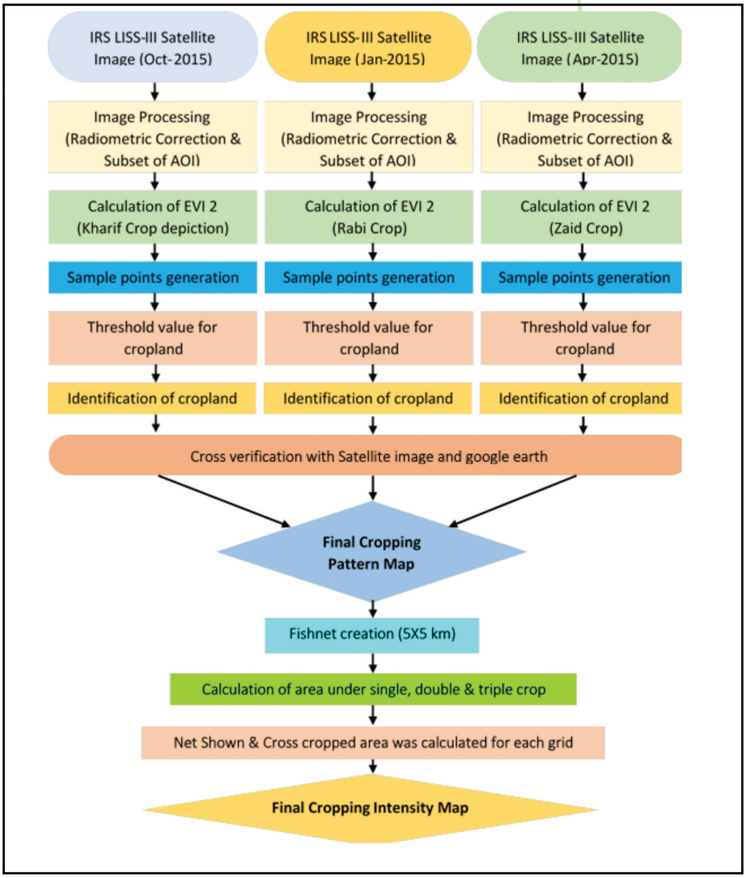

Fig: 3 Methodology

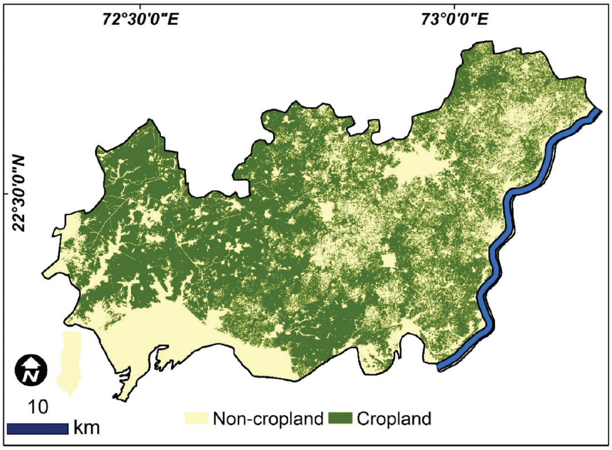

Fig:4 Kharif crop (EVI 2)

collected from the district agriculture division (District Panchayat Office, Anand, Gujrat). After collecting the satellite images, layer stacking was done along with radiometric and geometric correction followed by sub-setting of the study area with the district map. The natural vegetation of the study area was manually digitized from google earth and separated. For the identification of cropland two Band Enhanced Vegetation Index (EVI-2) method was applied. This method has similarity with the 3-band EVI, particularly when atmospheric effects are insignificant and the quality of the satellite images is good (Jiang et al. 2008). Maximum EVI 2 value shows dense vegetation cover. The formula for the EVI 2 method is the following:

$$EVI2 = \frac{2.5 * (\rho nir - \rho red)}{(\rho nir + 2.4 * \rho red + 1)} \qquad \text{(Jiang et al., 2008)}$$

Where,

ρred =Reflectance of the RED band,

ρnir = Reflectance of Near-infrared band.

For the identification of the croplands from EVI 2, initially, some tanning sample (Kharif-190, Rabi-100, Zaid-90) points were generated over each of the satellite images on the basis of false colour composite, texture and shape. The pixel locations were cross checked with the google earth image of that year to ensure cropland. Then these points were superimposed over the EVI 2 image followed by extraction of pixel values. From the extracted pixel values of different seasons, the lowest value was considered as the threshold. All the pixel values above the threshold were considered under cropland. The same process was applied for all three seasons. The final cropping pattern map was prepared after cross verification with satellite image and google earth. Once the croplands were extracted, the next step was to depict the crop combination of the region. For that purpose, the croplands of Kharif season (extracted from EVI 2) was used first. All the pixel values >1.00 were re-coded as '2'. Likewise, all the pixel values >0.50 of the threshold were re-coded as '3' for Rabi season and '4' for Zaid season threshold value > 0.41. All three re-coded images were summed with the help of raster calculator tools in Arc GIS. Then the output image shows the final crop combination. Area of 2, 3 and 4 pixel values show single crop combination, area of pixel values of 5 (2+3), 6 (2+4) and 7 (3+4) show double crop combination and area of 9 (2+3+4) pixel values show triple crop combination. All seven crop combinations (single Kharif, single Rabi, single Zaid, Kharif-Rabi double, Kharif-Zaid double, Rabi-Zaid double and triple crop) were marked by a different colour for the preparation of the final crop combination map. The area of croplands for the three seasons was compared with the original cropland data collected from the district agriculture department (Fig:3).

For the calculation of cropping intensity, grids of 5 km^2 area were created for the entire study area. From each grid, area of single, double and triple cropland was extracted and net sown and gross cropped area of each grid was calculated. Cropping intensity was calculated according to the following formula-

$$\text{Cropping Intensity} = \frac{\text{Gross Cropped Area}}{\text{Net Sown Area}} * 100$$

Results and Discussion

Cropping Pattern: Kharif

More than half of the area (56.42%) was under Kharif crop. The southwestern part of the study area was devoid of such crops while it is relatively lesser in the central part of the region. Sabarmati river flows in the western part of the study area and is considered as a potential source for irrigation for the Kharif crop. In the eastern part of the region river, Mahi flows but not much influence of the river was observed on the cropping pattern. The impact of Sabarmati is certainly more than Mahi in influencing the cropping pattern. The cropping intensity of the kharif crop was lesser on the western bank of Mahi and it increases towards the east. Besides, these two major rivers, many small rivers also flow in the western part and they affect the cropping pattern (Huang et al. 2015), mainly in the Kharif season (Fig: 4), as the Kharif crop requires more water (Mehta & Pandey, 2016).

Cropping Pattern: Rabi

The area under rabi crop was slightly higher (57.38%) than that of the Kharif. The crops were mostly concentrated in the central to the eastern part of the region and were less conspicuous in the west. Rabi crop was by and large absent in the south-western part. The presence of the canal played an important role in most of its growth. Higher concentration was observed in the central and eastern parts where canal irrigation was available (Fig: 5).

Cropping Pattern: Zaid

Zaid crop was found in 16.61% of Central Gujarat. This type of cropping pattern is mainly found in the central and eastern parts of the region. In the rest of the region, the concentration of Zaid crops was low. In the western part, this crop was noted only in a few fields. This type of crop is largely dependent on canal irrigation and hence, is strongly associated with the canal network (Fig: 6).

After extraction of the cropping pattern of the region, the results were compared with the actual area under crops in different seasons. It was found that the area under Karif crop extracted from EVI 2 was 1624.02 km^2 while the actual area under Kharif crop (procured from district agriculture division, district panchayat office, Anand, Gujarat) was 1614.09 km^2. In the case of the Rabi crop, the extracted area was 1645.91 km^2 and the actual area was 1651.70 km^2. The area under Zaid crop obtained from EVI 2 method was 480.90 km^2 and the actual area was 478.06 km^2. (Fig: 7)

The analysis shows that the difference between the actual area and the calculated area is almost the same clearly indicating the effectiveness of the method for the identification of cropping pattern

Crop Combination

Three types of crop combinations were identified: monoculture, two crop combinations and three crop combinations. Double crop combination (58.84%) is the dominating cropping pattern in this region followed by the three crop combination (21.87%). Only 19.29% area is under single crop and was found mainly near the coastal region and the influence of the seawater is one of controlling factor in this regard.

Monoculture

Mono crops covered 19.29% of the total cropland, dominating almost equally by Kharif (9.88%) and Rabi (9.25%). A small area was under Zaid (0.16%) single crop. Zaid crop was mainly confined to the central part whereas the western part had more of Kharif crop. Rabi crop was largely concentrated in central, north-east and in some parts of the west.

Double and triple crop combination

More than half of the total cropland (58.84%) was under two crop combinations. The

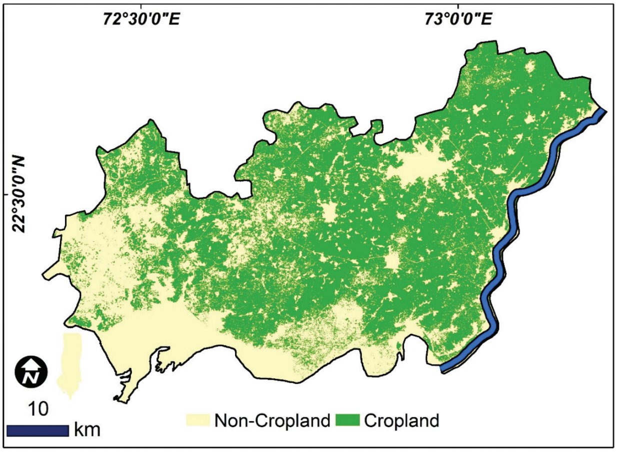

Fig:5 Rabi Crop (EVI 2)

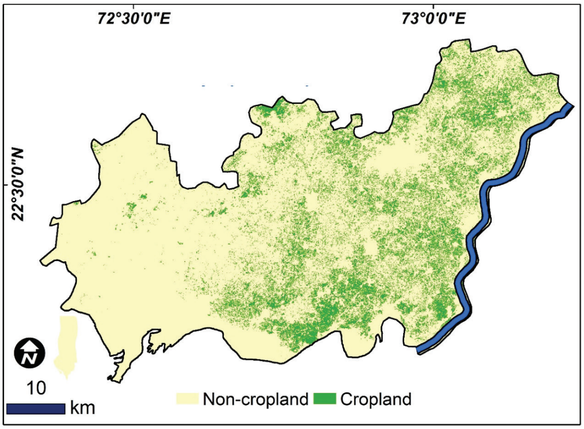

Fig:6 Zaid Crop (EVI 2)

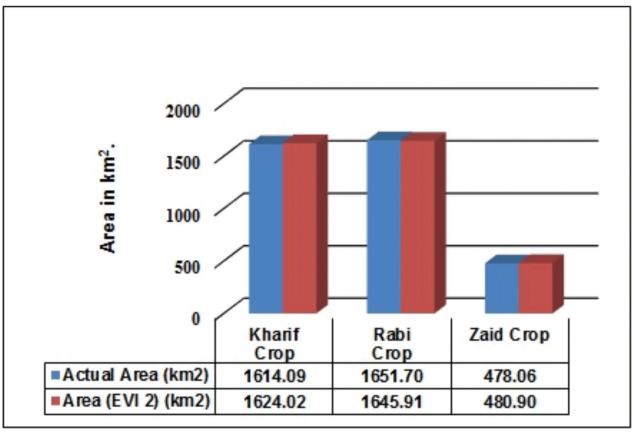

Fig:-7 Error Calculation

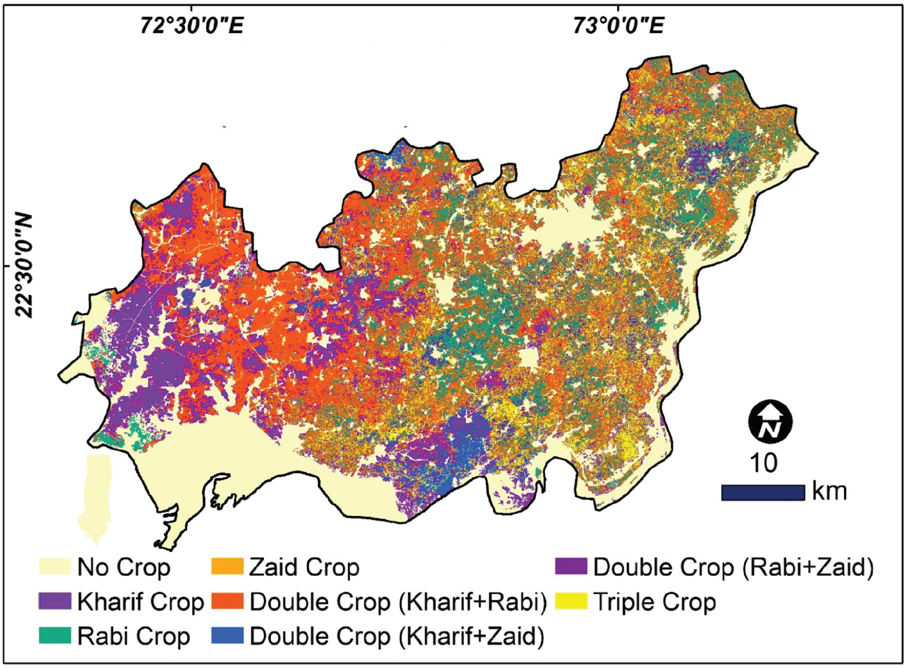

Fig:-8 Crop Combination Map

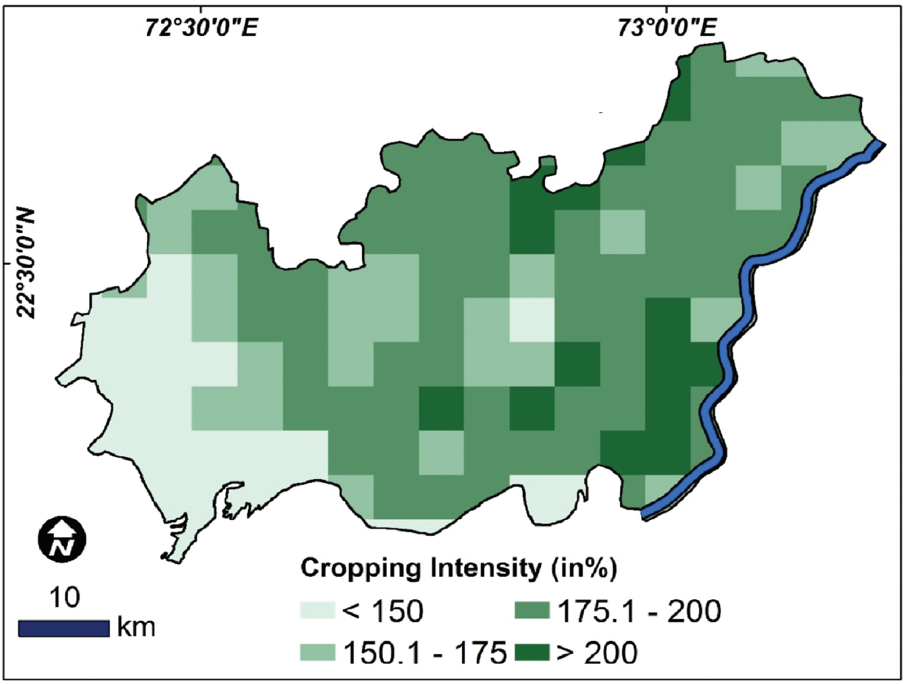

Fig:-9 Cropping Intensity Map

maximum cropland was under the Kharif-Rabi double crop combination (48.09%), while 4.16% cropland was under the Kharif-Zaid crop combination and 6.59% was the Rabi-Zaid crop combination. Kharif-Rabi crop combination was mainly observed in the western and central parts of the study area. Kharif-Zaid crop combination was mainly found in the south and north region. Rabi-Zaid crop combination is mainly noticed in the northeast and central part of central Gujarat. 21.87% of the total area had a triple crop combination. This type of crop combination was found throughout the central and north-east parts. (Fig: 8)

Cropping Intensity

A ratio between Net Sown Area (NSA) and Gross Cropped Area (GCA) is defined as cropping intensity. High cropping intensity indicates a multi-cropping pattern, whereas, low cropping intensity includes a mono cropping pattern. In this region, cropping intensity was classified into four categories. The highest (>200%) was found in some parts of central, north and south-east. 14.73% of total land had high cropping intensity. One-third of the region had cropping intensity between 175% -200%. This range was largely observed on the east and in the central part. 29.89% of the total area was under this category. Cropping intensity between 150% - 175% was noted in the central and parts of the western segment. <150% cropping intensity was noted in 18.27% of the total cropland. This range was observed mainly in the western part of the region. (Fig: 9)

Conclusion

The geospatial technique was adopted in the present study for the identification of cropping pattern and cropping intensity. From the study, it was found that band rationing technique is able to extract the cropping pattern with considerable accuracy. This method successfully identified the Kharif crop with 99.38% accuracy, followed by Rabi (99.36%) and Zaid (99.58%). It is found that the EVI2 method can extract both the cropping intensity and cropping pattern with a reasonable accuracy level. In addition to that, the impact of salinity nearer to the gulf of Khambhat was observed in controlling the cropping intensity to the greater extent. The vegetation index is a cost effective and time saving method in the study of cropping pattern and crop combination and is recommended for wider use.

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