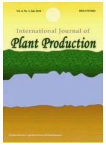

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Spatial dynamics for relative contribution of cropping pattern analysis on environment by integrating remote sensing and GIS

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Abstract

Agriculture resources reflected to be one of the most imperative renewable and dynamic natural resources. Agricultural sustainability has the premier priority in all countries, whether developed or developing. Cropping system analysis is indispensable for grinding the sustainability of agricultural science. Crop alternation is stated as growing one crop after another on the same piece of land in altered timings (seasons) without prejudicing the soil fertility. The study has been conducted for Fatehabad district of Haryana State of Indo-Gangetic plains in India. This paper generated cropping pattern and crop rotation maps of Fatehabad district. Multi-date IRS LISS-III digital data of different cropping seasons of 2007-08 have been used for this study. The present study relies on data from remote sensing combined with ground observations. Multi-date images of Rabi season images were geo-referenced using master images. Multi-date images of Kharif and single date image of summer seasons were geo-referenced with geo-referenced Rabi season image using image-to-image registrations and nearest neighborhood re-sampling method was applied. Multilayer stack were prepared for Kharif and Rabi cropping seasons. Stacked images of different seasons were classified using complete enumeration approach and unsupervised ISO-Data clustering classifier with district outside and non-agriculture mask based on some defined conditions such as the number of clusters, threshold, and number of iterations etc. A multi-phased unsupervised ISODATA classification was used for seasonal cropping pattern mapping. The results showed that in the area, a monophonic crop pattern was found in summer and major part of the district is lying as fallow and major crops are fodder, dhaicha & sunflower, but in winter, areas under dissimilar crop pattern had changed melodramatically.

Keywords: Accuracy assessment; Cropping pattern; Crop rotation.

Introduction

Crop identification and surface estimation for the purpose of agricultural statistics, through the combination of area frame sampling and estimation of regression with supervised classification of remote sensing data, are perhaps some of the best examples (Pinter et al., 2003). Remote sensing research and applications for irrigated agriculture (Casterad and Herrero, 1998; Bastiaanssen et al., 2000) and precision crop management have also been developed (Moran et al., 1997). Agriculture resources considered to be one of the most important renewable and dynamic natural resources. Crop rotation is the sequential growth of crops in a year. The agricultural crop production of principal agricultural crops in the country is usually estimated as a product of the area under the crop and the average yield per unit area of the crop. Cropping pattern of an area reflects the spatial arrangement of crops and inter-crop variability that exists. Multi-date data is essential to derive cropping patterns as in general there is more than one crop grown in a season with different growing calendar (Stockle et al., 1994). Majority of Indian farmers gets the major share of income from crop production. Therefore, it is very much important to select the right crop, in the right season so that maximum profit may be achieved. In selecting a crop for a season, both post and pre-season crops should also to be examined (Manjunath, 1990). In India a major project on Crop Acreage and Production Estimation (CAPE) has been carried out under the Remote Sensing Applications Mission by the Department of Agriculture and Cooperation and Department of Space to develop methodology for state level acreage and production estimation of important crops (Parihar et al., 1987).

A suitable crop rotation is typically based on a long-term plan, though, within limits, it need not be inflexible. It may vary in details from year to year and modifications can be made without disturbing the essential rotation plan. Cropping activities go on all the year around in India, provided water is available for crops. In northern India, there are two distinct seasons, Kharif (June to October) and Rabi (November to March). Crops grown between April and June are known as Zaid. In some parts of the country, there are no such distinct seasons, but there they have their own classification of seasons. Crop rotation has long been one of the most important practices you can adopt to be successful produced. Crop rotation has a positive influence on many important aspects of crop production, such as crop fertility, pest management and the protection of the environment. Crop rotation is an easy way to control diseases and insects at low cost. A simple definition of crop rotation is the planting of different crops in recurring succession in the same field. Research findings support the many benefits attributed to suitable crop rotation systems (Manjunath, 1990). Regarding the particular applications of remote sensing data to map cropping patterns or crop rotations that have been found in the literature, all the authors agree on the need to examine the time-series of remote sensing data of successive vegetation periods (Manavalan et al., 1995; Raupenstrauchk and Selige, 1998; Paoli et al., 2003). The methodology applied in these works is different in each case. Manavalan et al. (1995) detected changes in cropping patterns in two successive campaigns by developing an image differencing algorithm involving the near infrared and red bands (IRS-LISS-II data).

One particular example of the underutilization of remote sensing data in agriculture is the application to map multi-year cropping patterns and/or crop rotations. Although it is well known that one of the main advantages of remote sensing from satellites is the synoptic and repeated collection of data, which allows time-series of accurate information on the spatial distribution of crops over large areas (Panigrahy and Chakraborty, 1998; Bastiaanssen et al., 2000), few examples of these applications can be found in the literature (Herrmann and Kuhn, 1995; Raupenstrauchk and Selige, 1998; Paoli et al., 2003). Remote Sensing is one such technology, which is increasingly capable of providing precise and up-to-date information on the performance of agricultural systems, associated land degradation and land use change, thereby contributing to the process of effective management. Remote sensing is the science of making inferences about material objects from measurements, made at a distance, without coming into physical contact with the objects under study. There are several types of remote sensing systems used in agriculture but the most common is a passive system that senses the electromagnetic energy reflected from plants. (Kumar et al., 2013; Kumar et al., 2012; Tomar et al., 2013; Sharma et al., 2011).

This study was carried out in *Fatehabad* district of Haryana state in India. The main objective of this paper was to understand, document and model the changes in environmental conditions and to understand the dynamics of land use and cropping pattern, reflecting farmers' strategies in response to changes in environmental conditions. This paper illustrates that to achieve the above objectives; there is a need for integration of various kinds of information and data for a more holistic understanding of the biophysical conditions and socioeconomic circumstances that drive changes, using tools that facilitate such integration.

Material and Methods

Experimental site

Fatehabad is located at 29.52°N 75.45°E. It has an average elevation of 208 meters (682 feet). Fatehabad is one of the smallest districts in the Haryana and covers 5.69% area of the state. The district is surrounded by Punjab state in the north, Jind district in the east, the Sirsa district in the west direction, Hisar district and Rajasthan state in the south. Fatehabad district can be classified into tropical desert & steppe, arid and hot which is mainly dry with very hot summer and cold winter except during monsoon season when moist air of oceanic origin penetrates into the district. The hot weather season starts from mid-March to last week of the June followed by the south-west monsoon which lasts till September. The transition period from September to October forms the post-monsoon season. The winter season starts late in November and remains up to first week of March. The area being a flat terrain is conspicuous by absence of any well-defined natural drainage system but the Ghaggar River drains the northern part of the district. The locations of the study area are shown in Figure 1.

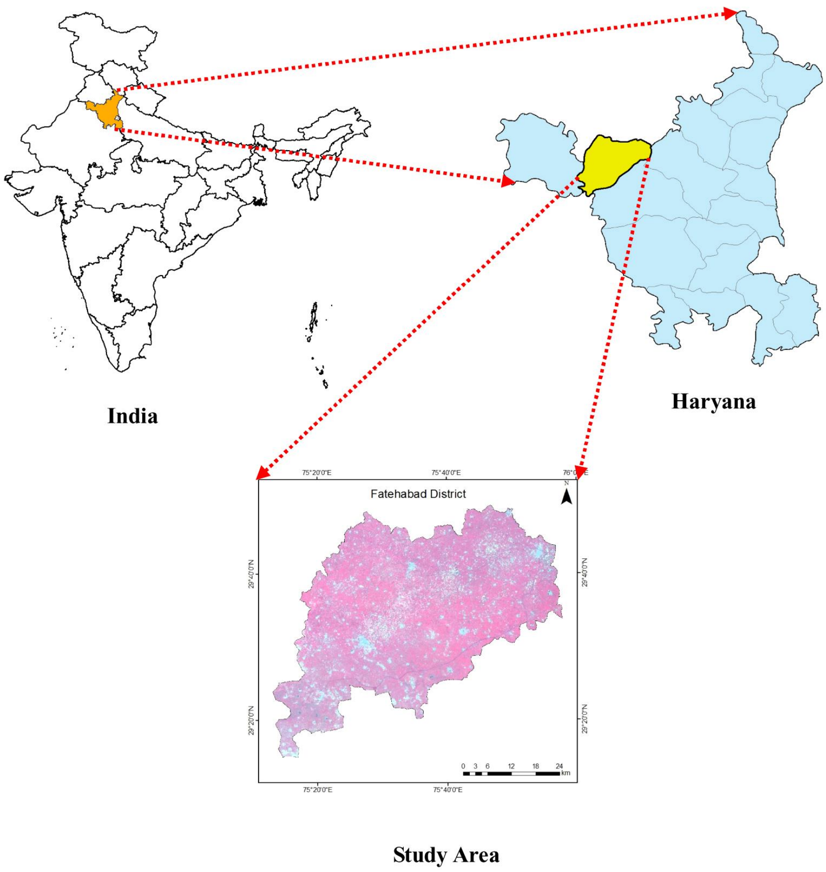

Figure 1. Location map of study area.

Data used

This study has been conducted for Fatehabad district of Indo-Gangetic Plains in Haryana, India for cropping pattern and crop rotation. Multi-date IRS LISS-III digital data of different cropping seasons of 2007-08 have been used for this study. For example to date data for Kharif season (August 08, 2007 and October 03, 2007), two dates' data for Rabi season (December 03, 2007 and March 11, 2008) and single date data for summer season (May 22, 2008). The present study relies on data from remote sensing combined with ground observations. For doing any research work various kinds of data are required to fulfill our research purposes. Remote sensing data from

LISS-III sensor on-board Indian Remote Sensing Satellite RESOURCESAT (IRS-P6 & 1D) of 2007-08 were used to generate seasonal cropping pattern maps. The Multi-date satellite data are used for different reasons given Table 1.

Table 1. Description of the satellite used data.

Season	Satellite	Sensor	Date of Acquisition	Path/Row
Kharif	IRS-P6 IRS-1D	LISS-III	August 08, 2007, October 03, 2007	94/50
Rabi	IRS-P6	LISS-III	December 03, 2007 March 11, 2008	94/50
Summer	IRS-P6	LISS-III	May 22 , 2008	94/50

Data analysis

Digital image analysis was carried out using ERDAS-9.3, Geometica 10.3 and ARC GIS 9.1 software package. Various digital image-processing techniques to obtain valuable information related to study and also to identify the classes and feature. Using ERDAS EMAGINE 9.3 software, the data were loaded onto the computer (Kumar et al., 2013). Image to image rectification technique was applied because it minimizes the residual rectification error. Multi-date images of Rabi season images were geo-referenced using master images. Multi-date images of Kharif and single date image of summer seasons were geo-referenced with geo-referenced Rabi season image using image-to-image registrations and nearest neighborhood re-sampling method was applied. Multilayer stack were prepared for Kharif and Rabi cropping seasons. Stacked images of different seasons were classified using complete enumeration approach and unsupervised ISO-Data clustering classifier with district outside and non-agriculture mask based on some defined conditions such as number of clusters, threshold and number of iterations. A multi-phased unsupervised ISODATA classification was used for seasonal cropping pattern mapping. Crops and associated features were identified using ground truth in the form for GPS locations. Mask of mixed classes was generated and image under the mask was reclassified till the desired accuracy achieved. Multi-spectral data of the Indian Remote Sensing Satellite (IRS) LISS-III multi-date data acquired in different cropping seasons resulted in more than 93% classification accuracy.

Outer boundary and non-agriculture mask

The district outer boundary mask and non-agriculture mask were combined together to be used in further approaches. For this, both the masks were loaded on one plane and by using certain logistic modeling approach. Following codes have been used for generating combined and outer mask.

NDVI profile of multi-date LISS-III images of different seasons

Normalize Differential Vegetation indices (NDVI) are quantitative measurements indicating the vigor of the crop. The geo-referenced images of different seasons were used as input to generate NDVI images. To avoid the negative values; the NDVI (spectral indices) was computed as follows.

$$NDVI = NIR - R / NIR + R * 100 + 100 + 0.5 \quad (1)$$

These NDVI images were displayed on screen using single band 8 bit unsigned channels. The district NDVI Image has been generated by using the following modeling.

%9 = (%3-%2)/(%3+%2)*100+100+0.5 (2)

Where %9 is an empty raster channel, %3 & %2 is the NIR & Red band of the image.

Generation of crop mask

Using logistic modeling approach, mask for major crops, other crops and fallow land classes from ISO-1 and ISO-2 of Kharif, Rabi and Summer seasons were. Following modeling has been used for generating wheat crop mask from ISO-1 and ISO-2 classification of Rabi season.

Cropping pattern analysis

After generating the individual mask of major crops, other crops and fallow of the different seasons, a logical combination of different image channels corresponding to crops grown in a season was used to generate the cropping pattern.

```
if%110=1 and%24=0 then
%24=1;
end if;
if%%112=1 and%24=0 then
%24=2;
end if;
if%%114=1 and%24=0 then
%24=3;                                                    (3)
end if;
if%%125=1 and%24=0 then
%24=4;
end if;
if%%5= 1and%24=0 then
%24=5;
end if;
```

The different image channels (raster) containing of mask wheat, sugarcane, other crops and fallow etc were combined to generate the Rabi season cropping pattern. Similarly, the image channels containing cotton, sugarcane, bajra/jowar, other crop, fallow etc. were combined to generate the Kharif cropping pattern. Thus combined image channels of major crops, other crops and fallow for Rabi, Kharif and Summer season respectively were generated for each block and Fatehabad.

Results

Kharif cropping pattern

Analysis by Remote Sensing data reflected that cotton and paddy are two major crops followed by gwar, bajra & sugarcane in Kharif season, which could be identified using multi-date Remote Sensing data. Paddy is mostly concentrated in Ghagghar belt of the district where bajra & gwar dominant in southern western upland sandy areas and sugarcane in central part of the district. Accuracy of remote sensing based area estimates assessed by computing percent Relative Deviation (%RD). The area of different crops and categories derived from Remote Sensing data shown in Table 2 and depicted in Figure 2. As sugarcane is a long duration crop available during Kharif season.

Table 2. Kharif season cropping pattern of study area.

S.No.	Class	Area (00'ha)
1.	Paddy	684
2.	Cotton	841
3.	Bajra	101
4.	Sugarcane	15
5.	Gwar	186
6.	Other Crops	368.7
7.	Fallow	35

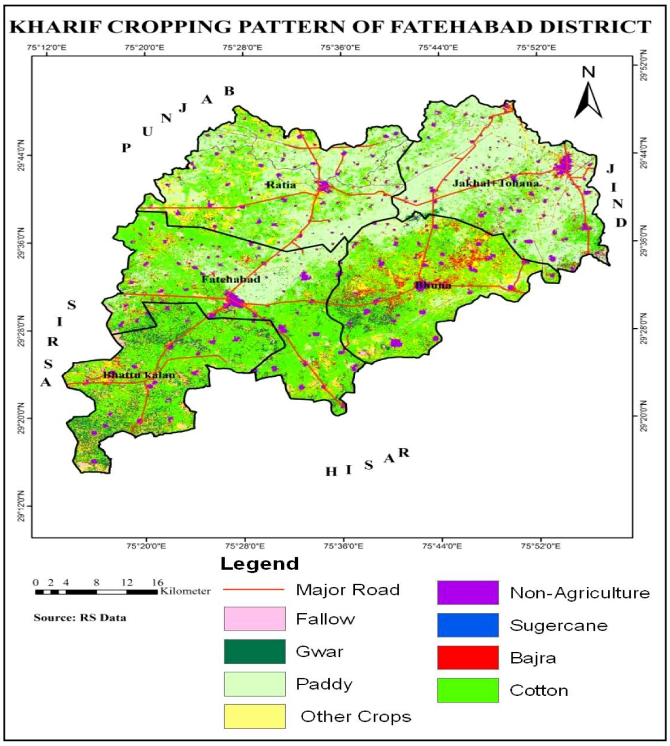

Figure 2. Kharif season cropping pattern map of study area.

Rabi cropping pattern

Wheat and mustard are the two major crops during Rabi season followed by sugarcane, gram and other crops identified using multi date LISS-III data. Crop wise areas estimates are depicted in Table 3 ad Figure 3. Wheat crop is evenly spread throughout the district and it occupies 1808 (00'ha) area. Mustard, gram and other crops are and occupy 77.2, 9.4 and 186.5 (00' ha) area respectively.

Table 3. Rabi season cropping pattern of study area.

S.No.	Class	Area (00'ha)
1.	Wheat	1808
2.	Mustard	77.2
3.	Gram	9.4
4.	Sugarcane	15
5.	Other Crops	186.5
6.	Fallow	145.8

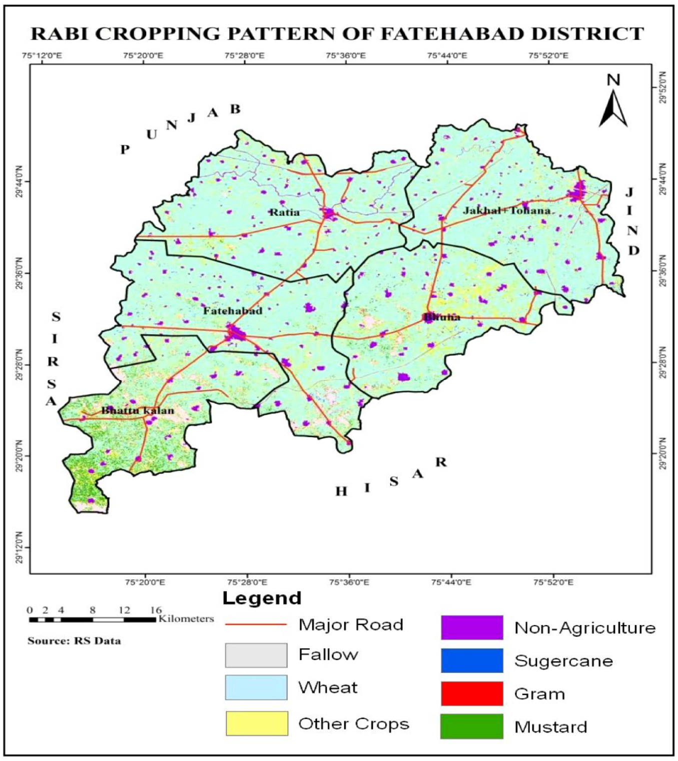

Figure 3. Rabi season cropping pattern map of study area.

Summer cropping pattern

Major agricultural land in the district is lying vacant as fallow during summer season it occupy 926.6 (00'ha). Besides fallow and other crops which occupy 499 (00'ha), fodder 596.9 (00'ha), dhaicha 166.6 (00'ha), vegetables 69.4 (00’ha), sunflower 34.56 (00’ha) & sugarcane 15 (00’ha) are the crops identified using LISS-III satellite data (Table 4 & Figure 4). As sugarcane is a long duration crop available during summer season also.

Table 4. Summer season cropping pattern of study area.

S.No.	Class	Area (00’ha)
1.	Sugarcane	15
2.	Sunflower	34.56
3.	Dhaicha	166.6
4.	Fodder	596.9
5.	Vegetables	69.4
6.	Other Crops	499
7.	Fallow	926.6

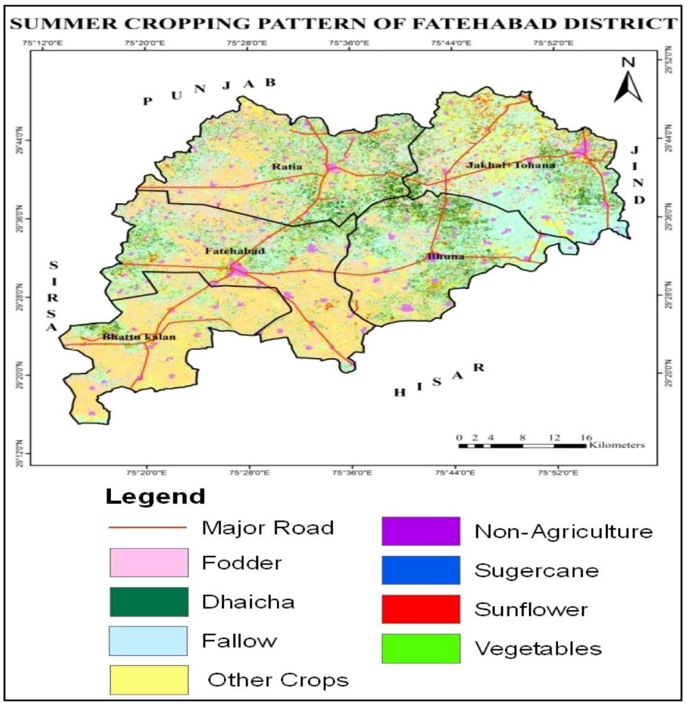

Figure 4. Summer season cropping pattern map of study area.

Accuracy assessment

Sample points for accuracy check were selected using a stratified random sampling design. The number of sample points was calculated using the following equation based on binomial probability theory given by (Fitzpatrick-Lins, 1981) as follows:

$$N = Z^2pq / E^2 \quad (4)$$

Where N = number of samples;
p = expected or calculated accuracy (%);
q = 100 – p;
E = allowable error; and
Z = standard normal deviate for the 95% two-tail confidence level = 1.96.

After evaluation of selected sample points in each reference data set, an error matrix was constructed, comparing map class labels to reference data labels for each land use class. Overall map accuracy and class-specific user and producer accuracies were calculated for each class. A KHAT statistics was computed for the 3 error matrices. Results of accuracy assessment are presented in Table 5 (Kharif season), Table 6 (Rabi season) and Table 7 (Summer season) respectively. Overall classification accuracies were 91.5% for Kharif season, 93.2% for Rabi season and 93.8% for Summer season.

Table 5. An Error matrix of Kharif season cropping pattern.

Kharif Crop	Paddy	Cotton	Bajra	Sugarcane	Gwar	Other Crops	Fallow	P.A. (%)	U.A. (%)
Paddy	72	0	0	0	0	0	2	98	97
Cotton	0	73	7	0	0	0	0	96	91
Bajra	0	3	76	0	0	0	0	91	96
Sugarcane	0	0	0	68	6	0	0	100	91
Gwar	0	0	0	0	80	3	2	89	94
Other Crops	1	0	0	0	3	79	2	88	92
Fallow	0	0	0	0	0	7	67	91	90

P.A. = Producer’s Accuracy; U.A. = User’s Accuracy.

Table 6. An Error matrix of Rabi season cropping pattern.

Rabi Crop	Wheat	Mustard	Gram	Sugarcane	Other Crops	Fallow	P.A. (%)	U.A. (%)
Wheat	81	0	0	0	0	0	100	100
Mustard	0	70	2	0	0	0	100	97
Gram	0	0	65	0	0	0	95	100
Sugarcane	0	0	0	68	7	3	100	87
Other Crops	0	0	0	0	80	12	91	86
Fallow	0	0	1	0	0	70	82	98

P.A. = Producer's Accuracy; U.A. = User's Accuracy.

Table 7. An Error matrix of Summer season cropping pattern.

Summer Crop	Sugarcane	Sunflower	Dhaicha	Fodder	Vegetables	Other Crops	Fallow	P.A. (%)	U.A. (%)
Sugarcane	71	0	0	0	0	0	0	100	100
Sunflower	0	67	2	0	0	0	0	100	97
Dhaicha	0	0	78	0	0	0	0	97	100
Fodder	0	0	0	76	2	1	0	100	96
Vegetables	0	0	0	0	69	4	1	97	93
Other Crops	0	0	0	0	0	72	0	81	100
Fallow	0	0	0	0	0	11	70	98	86

P.A. = Producer's Accuracy; U.A. = User's Accuracy.

Crop rotation

Crop Rotation shows sequential planting of crops in time. It indicates that Fatehabad has the major crop rotations of cotton-wheat-other Crops, paddy-wheat-fallow & paddy-wheat-other crops (Figure 5). This may be due to the fact that of cotton, paddy and wheat are the major crops of Kharif and Rabi seasons respectively. Cotton-wheat-other crops & cotton-wheat-fallow rotations are spread in whole district expect in Ghagghar flood plain & southern western part. These rotations are dominant is upland sandy soil having irrigation facilities (Table 8).

Relative deviation is computed for RS 2007-08 estimates of major crops of Kharif and Rabi seasons of Fatehabad with the same year Department of Agriculture (DOA) i.e., 2007-08 estimates (Table 9) The DOA data of summer season crops except sugarcane is not available so (%RD) is not computed for other crops.

Table 8. Crop rotation statistics of study area.

S.No.	Classes of various crops	Area (00'ha)	Area (%)
1	Cotton-Wheat-Other Crops	45994.00	18.97
2	Paddy-Wheat-Fallow	36867.46	15.21
3	Paddy-Wheat-Other Crops	32115.54	13.25
4	Cotton-Wheat-Fallow	25708.19	10.6
5	Bajra/Gwar/Fallow-Wheat-Other Crops	17975.4	7.41
6	Other Crops-Wheat-Other Crops	14344.51	5.92
7	Other Crops-Wheat-Fallow	9502.97	3.92
8	Other Crops-Fallow/Other Crop-Other Crops	7401.76	3.05
9	Cotton/Paddy-Fallow-Vegetables	4295.83	1.77
10	Bajra/Gwar-OtherCrops/Fallow-Other rops/Fallow	4183.28	1.73
11	Paddy-Fallow/Other Crops-Other Crops/Fallow	3425.84	1.41
12	Bajra/Fallow/Gwar-Mustard-Other Crops/fallow	2680.49	1.11
13	Cotton-Fallow-Other Crops	2152.81	0.89
14	Fallow/Gwar-Fallow-Other Crops	2106.79	0.87
15	Cotton-Other Crops-Fallow	1639.25	0.68
16	Other Crops-Other Crops -Other Crops/Fallow	1635.27	0.67
17	Cotton-Mustard-Other Crops	1628.02	0.67
18	Sugarcane Based	1605.38	0.66
19	Other Crops-Fallow-Fallow	1602.56	0.66
20	Other Crops-Mustard-Other Crops/Vegetables	1249.35	0.52
21	Other Rotation	14685.67	6.06
22	Non Agriculture area	3.97	3.97

Table 9. Relative deviation for crops of study area.

Season	Class	Area (00'ha)	BES	% RD
Kharif	Paddy	684.7	715	-4.24
	Cotton	841	853	-1.41
	Bajra	101	107	-5.61
	Sugarcane	15	14	7.14
Rabi	Wheat	1808	1874	-9.88
	Mustard	77.2	79	-2.32
	Gram	9.4	9	4.44
	Sugarcane	15	14	7.14
Summer	Sugarcane	15	14	7.14

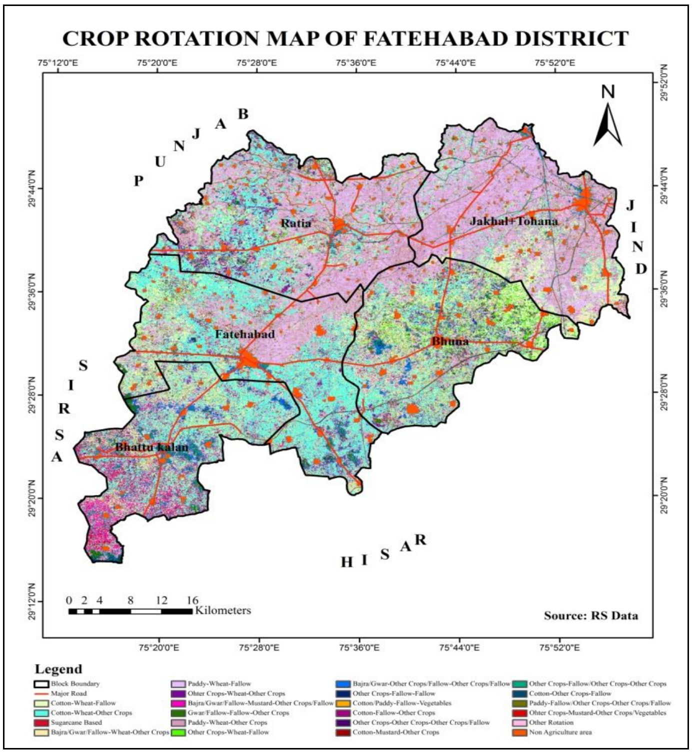

Figure 5. Crop rotation map of study area.

Discussion

Remote Sensing data analysis showed that cotton is major crop followed by paddy. Paddy is concentrated in central & north eastern part of the district while in rest of the part cotton is major corp. Wheat is major crop of Rabi season & available in whole district except south-western sandy upland where mustard is major crop. During summer season major part of the district is lying as fallow and major crops are fodder, dhaicha & sunflower. Sugarcane is a long duration crop and observed in all there cropping seasons.

Conclusion

Thus, the production system is a complex one and the interactions are intricately woven and interlinked, Cropping System Mapping is essential to understand the total agriculture scenario of a region, and thereby to carry out proper planning for agricultural development. Due to spatial resolution of RS data minor & non-continuous crop are not separated and considered as other crops. It was observed that cotton-wheat-other crops & cotton-wheat-fallow are major rotations in the district except Ghagghar flood plain where paddy-wheat-fallow and paddy-wheat-other crops are the major rotations.

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