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Manuscript Type: Original Article

Title: Multi-Temporal Landsat8 Satellite data based Crops and other Land Use spatial estimation in Okara district of Pakistan

Running Title: Optical Satellite Data for Land Use Mapping

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Novelty statement:

1. Satellite data use for detailed field level quantification of crops acreage and land use mapping.
2. Developed an integrated approach based on satellite and ground survey informations.
3. Availability of agricultural land use statistics during cropping season for policy and decision makers by improving timelines by 3-4 months in view of publishing of official crops statistics.
4. Satellite data have synoptic view of whole population so samples based population estimates can easily be improved.
5. In Pakistan, till now most of available official agricultural statistics are non-spatial which can be improved by adding spatial element of lat/long.

Abstract:

Developing countries like Pakistan is among those where lack of adoption to science and technology advancement is a major constraint for Satellite Remote Sensing use in crops and land use land cover digital information generation. Exponential rise in country population, increased food demand, limiting natural resources coupled with migration of rural community to urban areas had further led to skewed official statistics. This study is an attempt to demonstrate the possible use of freely available satellite data like Landsat8 under complex cropping system of Okara district of Punjab, Pakistan. An Integrated approach has been developed for the satellite data based crops and land use/cover spatial area estimation. The resultant quality was found above 96% with Kappa statistics of 0.95. Land utilization statistics provided detail information about cropping patterns as well as land use land cover status. Rice was recorded as most dominating crop in term of cultivation area of around 0.165 million ha followed by autumn maize 0.074 million ha, Fallow crop fields 0.067 million ha and Sorghum 0.047 million ha. Other minor crops observed were potato, fodder and cotton being cultivated on less than 0.010 million ha. Population settlements were observed over an area of around 0.081 million ha of land.

Keywords: Landsat8, Multi-Temporal, Crops Statistics, Land Use Land Cover; Pakistan

1. Introduction

After independence in 1947, Pakistan's agriculture especially crops statistics were collected through opinion-based ground surveys to get some estimates that can act as base for agriculture policy decisions in perspective food security issues and better natural resource management (Kalair, 2012). Lack of adoption to science and technology advancement, such system has lost its reliability. Furthermore, exponential rise in population (Mahsud-Dorman, 2007), food demand,

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limiting natural resources coupled with migration of rural community to urban areas had further led to skewed agricultural statistics.

Current adopted system in Pakistan of provincial crop reporting services (PCRSs) came into being as independent organization in late 1970s, and by the early 1980s, data collection techniques for both people and crops changed. With technical assistance from foreign agencies like United States Department of Agriculture (USDA), a system based partially on remote sensing satellites came into being but not used in improvement of land use and food security policies. This placed system is based on village master sampling system design. Randomly selected villages across districts in province are used estimate crops area and yields, and extrapolate the village data to the district level. There are three timelines: 'first estimates', 'second estimates' and 'final estimates'. For example, in wheat crops, the first estimate is made on 1 February, the second on 1 April and the last on 1 August of each year (PCRS).

Pakistan is predominantly agricultural country with 20.7 million people, Pakistan still relies on an irrigation network developed during the British rule over the sub-continent with few additions like Tarbela and Mangla dams along with link canals (GoP, 2018; GoP, 2017]. At independence in 1947, the irrigated area was around 10.75 million hectares, which has increased to over 18 million hectares (Schultz and Thatte, 2004). Pakistan's obsolete crops monitoring system needs a revamp (Akhtar, 2012). The gaps are evident. Generally, the agricultural statistics lag by three to four months after crop harvesting, leading to some irrational decision making on import and export of agriculture commodities, which is influenced more by the political and private sectors than by reliable crop statistics. Consequently, it is critical to develop better

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agricultural monitoring capabilities able to provide timely information about crop status, crop area and yield forecasts (Brown, 2005). Earth Observation (EO) satellites data can clearly contribute to this objective as a proven source for transparent, timely, accurate and consistent information on the agricultural productivity at global and regional scales (FAO, 2007; Soares et al., 2011).

Satellite Remote Sensing crops acreage and land use land cover mapping is useful as advance information to the policy planners even if it is available with slightly lesser accuracy. Moreover such technologies are performing well through in-season crop acreage assessment and provide regular crop updates to planners and policy makers. It may be a particularly useful tool for countries with higher food security risks in taking ameliorating measures much in advance (Srivastava, 2015).

Since its inception in 1972, the Landsat program has provided an invaluable archive of EO data at 16 day repeat periods (Whitecraft et al., 2015). It will allow providing unprecedented estimates on crop area extent, crop type and state, which can serve as indicators for the agricultural productivity of the respective region (Bontemps et al., 2015). In practice, the user can map as many crop types as he wants, providing that he has the corresponding in situ data.

Pakistan needs to move towards a combined system of remote sensing, geographical information system (GIS). The most significant benefit will be timely generation of reliable crop statistics before crop harvesting begins, with confidence that the estimates are correct in 95 per cent of the instances, and do not lag behind actual crop harvesting. Okara district of the Punjab province in Pakistan is among most fertile agricultural land with population of more than 3 million (GoP, 2017). Complex cropping system is the reason for the selection of the district to evaluate the effectiveness of the Landsat8 satellite in discriminating multiple crops within a season and significance of ground information integration.

2. Materials and Methods

An Integrated approach has been developed for the satellite data based crops spatial area estimation for the Okara district of Punjab (Bontemps, et al., 2015; Akhtar, 2013; Ahmad, et al., 2015; Hassan, et al., 2017) (Fig. 1). Okara district area is around 4225 Square Kilometers and spread across 30^0 to 32^0 Latitude and 73^0 to 75^0 Longitude. Four major steps are carried out to develop first time detailed spatial information layers for all crops and other land use land cover for Kharif season 2017-2018. These steps include; (1) Satellites data mining for availability (i) Crop specific satellite data calendar development to use seasonal Multi-temporal images to differentiate the different crops in final output (ii) Selected images downloading after quality assessment of cloud cover less than 5% (2) Satellite data processing (i) Satellite data catalogue (ii) Pre-processing using python data processing tool for conversion of image bits to pixel radiance and reflectance values (3) Satellite data digital image processing in dedicated software's (i) Spatial gridding and Stratified sampling (ii) Ground Truth Survey was carried out collect reference crop fields and make spectral library for image processing based on latitude/longitude value and geo-tagged pictures (iii) Supervised seasonal satellite data classification (4) Geospatial analytics to generate the crop field digital layers and associated statistics (i) Classification accuracy assessment (ii) Raster to Vector Conversion (iii) Manual Refinements and (iv) Spatial Statistics and Maps.

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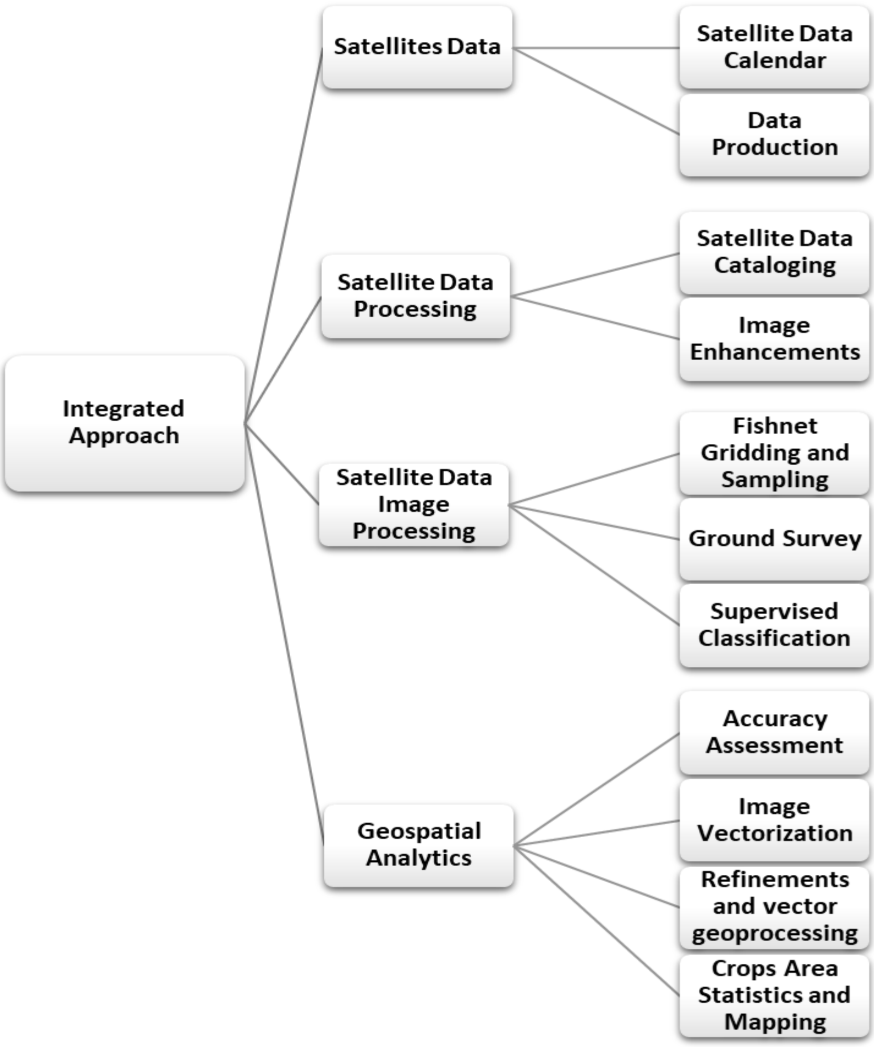
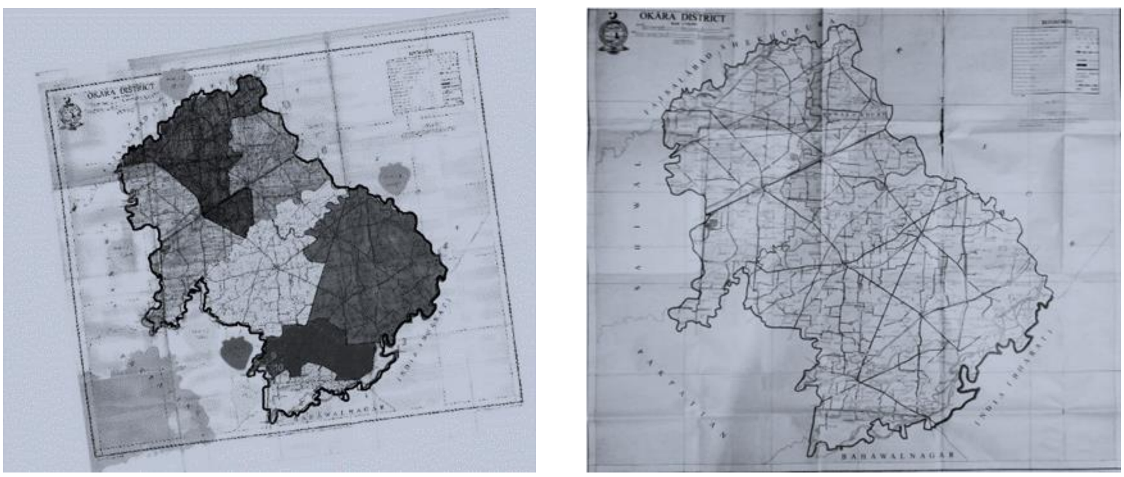


Fig. 1: Workflow diagram of the processing chain



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Non Geo-referenced Scanned Map Geo-referenced scanned map of Okara

Fig. 2: Geo-referencing of Survey of Pakistan district maps and extraction of Zonal boundary

Firstly, survey of Pakistan district map was purchased from market, scanned and geo-referenced using specialized image processing soft wares (Fig. 2). Pioneer Pakistan Seed Company provided colour coded paper map showing crops seed market specific catchment zones (Fig. 3).

Secondly, Landsat 8 Satellite data were used for successful mapping of different crops i.e., Autumn Maize, Sorghum, Sugarcane and Rice crops in Okara. Brief specifications are (i) Optical Satellite (ii) 15m Panchromatic image (iii) 30m Multispectral images (iv) 185km x 185km Satellite image size and (v) 16 days revisit of same geographical area.

Seven different dated satellite images covering Kharif cropping season 2017—18 were downloaded from the www.earthexplorer.com (Fig. 4). Temporal coverage starts from end of March to end of August, 2017.

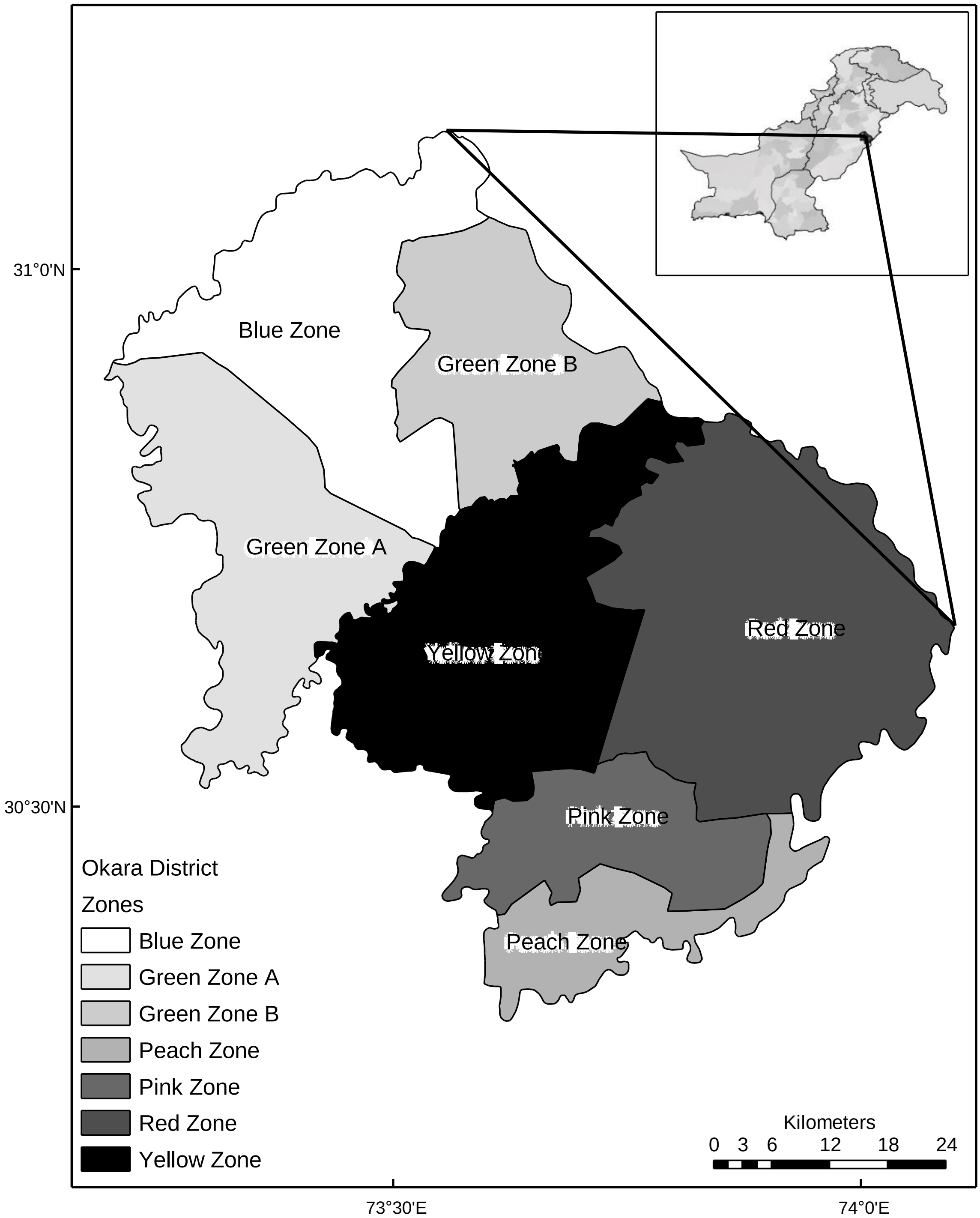

Fig. 3: Study area showing the different zones

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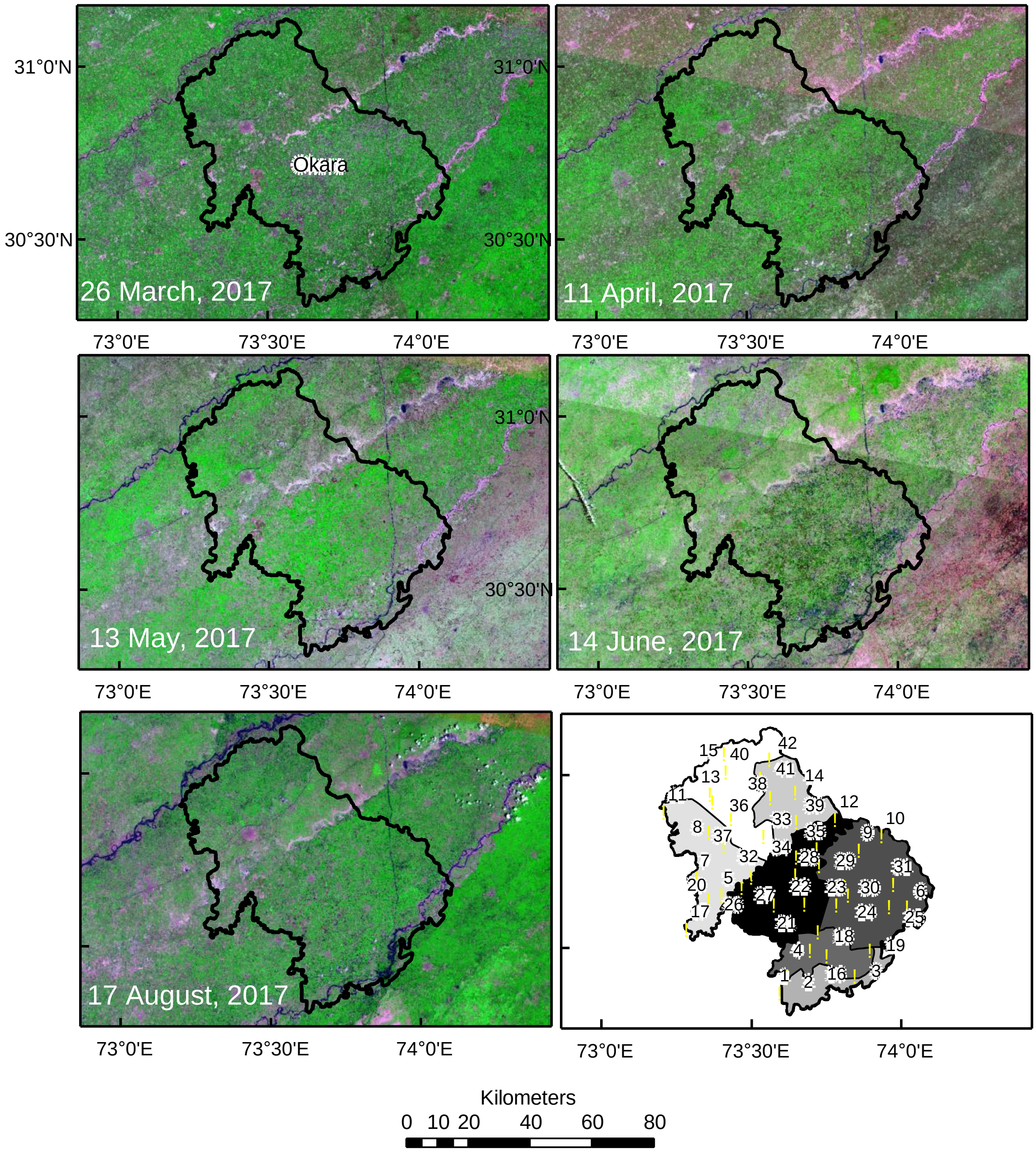

Fig. 4: Landsat 8 Multi-temporal satellite seasonal data and ground survey locations.

A special stratified random sampling is developed in python and used in ArcGIS software. This tool creates a new output feature class containing sample points. First, a polygon of study

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area is divided into areal units. The shape and size of areal units are defined through tessellation parameters. Then, a sample point is placed randomly within each tile. Geometric shape for tessellation can be chosen from three options: hexagon, rectangle, and triangle. For hexagon and triangle, the user only needs to specify the side length parameter to define the size of tessellation tiles. For rectangle, the user needs to specify the side length and the side height parameters. This tool may also create another output feature class containing tessellation tiles. Tessellation may be tilted towards the orientation of the smallest area rectangle enclosing the study area. Tilt option is purposed to get the best fit of tessellation in covering the study area. Study area i.e., Okara district was divided into five zones and forty two locations were selected. Each location is visited by team of four members include field experts and local person of that zone.

Ground Truth Survey (GTS) for maize monitoring in Okara was conducted from 18 to 28 September, 2017 to collect information of different cultivated crops fields around the selected 42 sampling sites. Each location was visited by team of four members include field experts and local person of that zone. Team reached at location with the help of Google maps application and field expert by using survey maps. After reaching the main location twenty seven fields were visited around main location with in diameter of approximately 1 km. Data are recorded on survey data sheet i.e. latitude, longitude (by using GPS Test) of the field, crop name, major crop of area, current status of crop and four geo-tagged pictures at each survey location (Fig 5). Development of accurate spectral signature is the most vital step in land cover classification (Soares et al., 2011; Srivastava, 2015). The clear and unblended representative training samples from the ground truth materials are drawn and are used as spectral signatures of two different dates.

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This information is used to develop the spectral signature library for the satellite image processing through standard algorithms. Geo-location of each crop field was recorded as longitude and latitude value through smartphone application GPS Test and capturing of geo-tagged pictures of crops.

Some of the collected information is also used an independent information for accuracy assessment of extracted crops field information from the satellite data.

Survey Data Collection Sheet

Date/Day: ______________________ **Survey point no:** ______________________

Zone Name: ______________________ **Nearby Village or Location:** ______________

Tehsil Name: ______________________ **Surveyor Name:** ______________________

Field No	Latitude	Longitude	Crop Name	Major Crop	Picture #	Remarks

Fig. 5: Survey Data Collection Form

3. Results

Geospatial analysis were carried out to estimate the different crops cultivated area through extraction of crops fields from the high resolution optical Landsat 8 satellite data acquired within the kharif growing season 201718. Ground truth survey field information was converted into spectral information by extracting satellite images pixel values and used a training samples. The collected information include around 1100 crops field's information (Fig. 6). This information was used to train the satellite data processing algorithm to generate the land use / cover thematic or classified information layer. This processed crops information layer was analyzed for quality based on confusion matrix analysis. The resultant quality was found above 96% with Kappa statistics of 0.95. Gaussian maximum likelihood technique revealed good results for the rice, cotton, autumn maize and fodder crops along with water and settlements features Table 1.

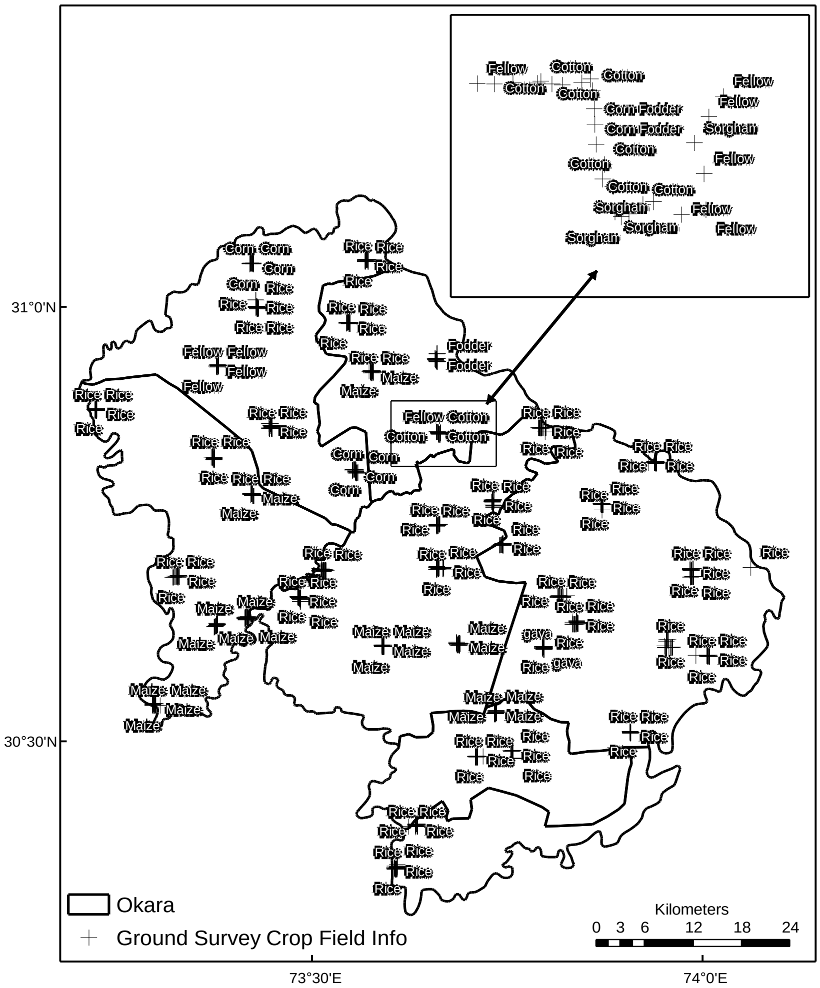

Fig. 6: Ground campaign was carried out in all seven zones of the districts and shows well distribution of the crops fields

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Table 1: Supervised classification of the Temporal stacked Landsat8 images of March-August, 2017 was carried out.

Land Use Class	Producer	User	Overall Accuracy
	(Percent)		
Rice	89.1	98.1	93.6
Sorghum	93.2	27.8	60.5
Sugarcane	95.9	74.3	85.1
Fodder	90.7	98.0	94.3
Maize	91.0	82.3	86.7
Cotton	100.0	100.0	100.0
Settlements	100.0	100.0	100.0
Water	100.0	100.0	100.0
Overall Accuracy		96.60%	
Kappa Coefficient		0.95	

Classified thematic raster dataset was converted into vector layer to manually refine based on ground collected information and expert knowledge on image interpretation.

3.1. Zone specific spatial statistics

Blue zone is characterized by total area of 68653 hectares of surface area and located in north central part of district. Satellite data based crops estimates showed that Rice is the major crop with an area of approx. 21114 ha (30.8%) followed by autumn Maize with area of 14686 ha (21.4%), Sorghum cultivated area of 8604 ha (12.5%) and Sugarcane under area of 4029 ha (5.9%).

Green zone A is characterized by total area of 63718 hectares of surface area and located in north western part of district. Satellite data based crops estimates showed that autumn Maize is

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the major crop with an area of approx. 14564 ha (22.9%) followed by Rice with area of 13120 ha (20.6%), Sorghum cultivated area of 7613 ha (11.9%) and Sugarcane under area of 3812 ha (6.0%).

Green zone B is characterized by total area of 45677 hectares of surface area and located in north eastern part of district. Satellite data based crops estimates showed that Rice is the major crop with an area of approx. 10756 ha (23.5%) followed by Sorghum with area of 7761 ha (17.0%), Sugarcane cultivated area of 4588 ha (10.0%) and autumn Maize under area of 4195 ha (9.2%).

Yellow zone is characterized by total area of 82439 hectares of surface area and located in central part of district. Satellite data based crops estimates showed that Rice is the major crop with an area of approx. 35985 ha (43.7%) followed by autumn Maize with area of 17145 ha (20.8%), Sorghum cultivated area of 7958 ha (9.7%) and Sugarcane under area of 2022 ha (2.5%).

Red zone is characterized by total area of 103799 hectares of surface area and located in south eastern part of district. Satellite data based crops estimates showed that Rice is the major crop with an area of approx. 55638 ha (53.6%) followed by autumn Maize with area of 15301 ha (14.7%), Sorghum cultivated area of 10589 ha (10.2%) and Sugarcane under area of 1966 ha (1.9%).

Pink zone is characterized by total area of 33565 hectares of surface area and located in south western part of district. Satellite data based crops estimates showed that Rice is the major crop with an area of approx. 16676 ha (49.7%) followed by autumn Maize with area of 6379 ha (19.0%), Sorghum cultivated area of 2780 ha (8.3%) and Sugarcane under area of 610 ha (1.8%).

Peach zone is characterized by total area of 24648 hectares of surface area and located in south eastern part of district. Satellite data based crops estimates showed that Rice is the major

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crop with an area of approx. 11325 ha (45.9%) followed by Sorghum with area of 1942 ha (7.9%), autumn Maize cultivated area of 1757 ha (7.1%) and Sugarcane under area of 429 ha (1.7%).

3.2. Crops specific spatial statistics

Similarly, crop wise satellite data based cultivated area was compiled (Table 1– 4). Rice crop was found as dominated kharif crop in Okara district representing around 39.0 % (164614 ha) of cultivated land. Red zone was recorded with maximum cultivation of rice crop followed by Yellow zone and Blue zone. Least rice growing zones were Green zone B&A.

Table 2: Satellite data extracted rice crop estimates by zones

S.No	Zones	Zone Area	Rice 2017 Area		Rice Area Share
		in ha	in ha	in acres	Percent
1	Blue Zone	68653.4	21114.0	52172.7	30.8
2	Green Zone	63717.9	13120.0	32419.5	20.6
3	Green Zone	45676.5	10756.0	26578.1	23.5
4	Peach Zone	24647.6	11325.0	27984.1	45.9
5	Pink Zone	33565.4	16676.0	41206.4	49.7
6	Red Zone	103799.0	55638.0	137481.5	53.6
7	Yellow Zone	82438.8	35985.0	88918.9	43.7
Total		422498.6	164614.0	406761.2	39.0

Autumn maize crop was found as second major kharif crop in Okara district representing around 17.5 % (74027 ha) of cultivated land. Yellow zone was recorded with maximum cultivation followed by Red zone and Blue zone. Least maize growing zones were Peach and Green zone B.

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Table 3: Satellite data extracted autumn maize crop estimates by zones

S.No	Zones	Zone Area	Autumn Maize 2017 Area		Maize Area Share
		in ha	in ha	in acres	Percent
1	Blue Zone	68653.4	14686	36289.1	21.4
2	Green Zone	63717.9	14564	35987.6	22.9
3	Green Zone	45676.5	4195	10365.8	9.2
4	Peach Zone	24647.6	1757	4341.5	7.1
5	Pink Zone	33565.4	6379	15762.5	19.0
6	Red Zone	103799.0	15301	37808.8	14.7
7	Yellow Zone	82438.8	17145	42365.3	20.8
Total		422498.6	74027.0	182920.7	17.5

Sorghum crop was found as third major kharif crop in Okara district representing around 11.2 % (47247 ha) of cultivated land. Red zone was recorded with maximum cultivation followed by Blue zone and Yellow zone. Least Sorghum growing zones were Peach and Pink zone.

Table 4: Satellite data extracted sorghum crop estimates by zones

S.No	Zones	Zone Area	Sorghum 2017 Area		Sorghum Area Share
		in ha	in ha	in acres	Percent
1	Blue Zone	68653.4	8604.0	21260.5	12.5
2	Green Zone	63717.9	7613.0	18811.7	11.9
3	Green Zone	45676.5	7761.0	19177.4	17.0
4	Peach Zone	24647.6	1942.0	4798.7	7.9
5	Pink Zone	33565.4	2780.0	6869.4	8.3
6	Red Zone	103799.0	10589.0	26165.4	10.2
7	Yellow Zone	82438.8	7958.0	19664.2	9.7
Total		422498.6	47247.0	116747.3	11.2

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Sugarcane crop was found as fourth major kharif crop in Okara district representing around 4.1 % (17456 ha) of cultivated land. Green zone B was recorded with maximum cultivation followed by Blue zone and Green zone A. Least sugarcane growing zones were Peach and Pink zone.

Table 5: Satellite data extracted sugarcane crop estimates by zones

S.No	Zones	Zone Area in ha	Sugarcane 2017 Area in ha	Sugarcane 2017 Area in acres	Sugarcane Area Share Percent
1	Blue Zone	68653.4	4029.0	9955.7	5.9
2	Green Zone	63717.9	3812.0	9419.5	6.0
3	Green Zone	45676.5	4588.0	11336.9	10.0
4	Peach Zone	24647.6	429.0	1060.1	1.7
5	Pink Zone	33565.4	610.0	1507.3	1.8
6	Red Zone	103799.0	1966.0	4858.0	1.9
7	Yellow Zone	82438.8	2022.0	4996.4	2.5
Total		422498.6	17456.0	43133.8	4.1

3.3. Spatial Land Utlization statistics

Land utilization statistics provided detail information about cropping patterns as well as land use land cover status (Fig. 7). Rice was recorded as most dominating crop in term of cultivation area of around 0.165 million ha followed by autumn maize 0.074 million ha, Fallow crop fields 0.067 million ha and Sorghum 0.047 million ha. Other minor crops observed were potato, fodder and cotton being cultivated on less than 0.010 million ha. Human settlements were observed over an area of around 0.081 million ha of land in Okara district.

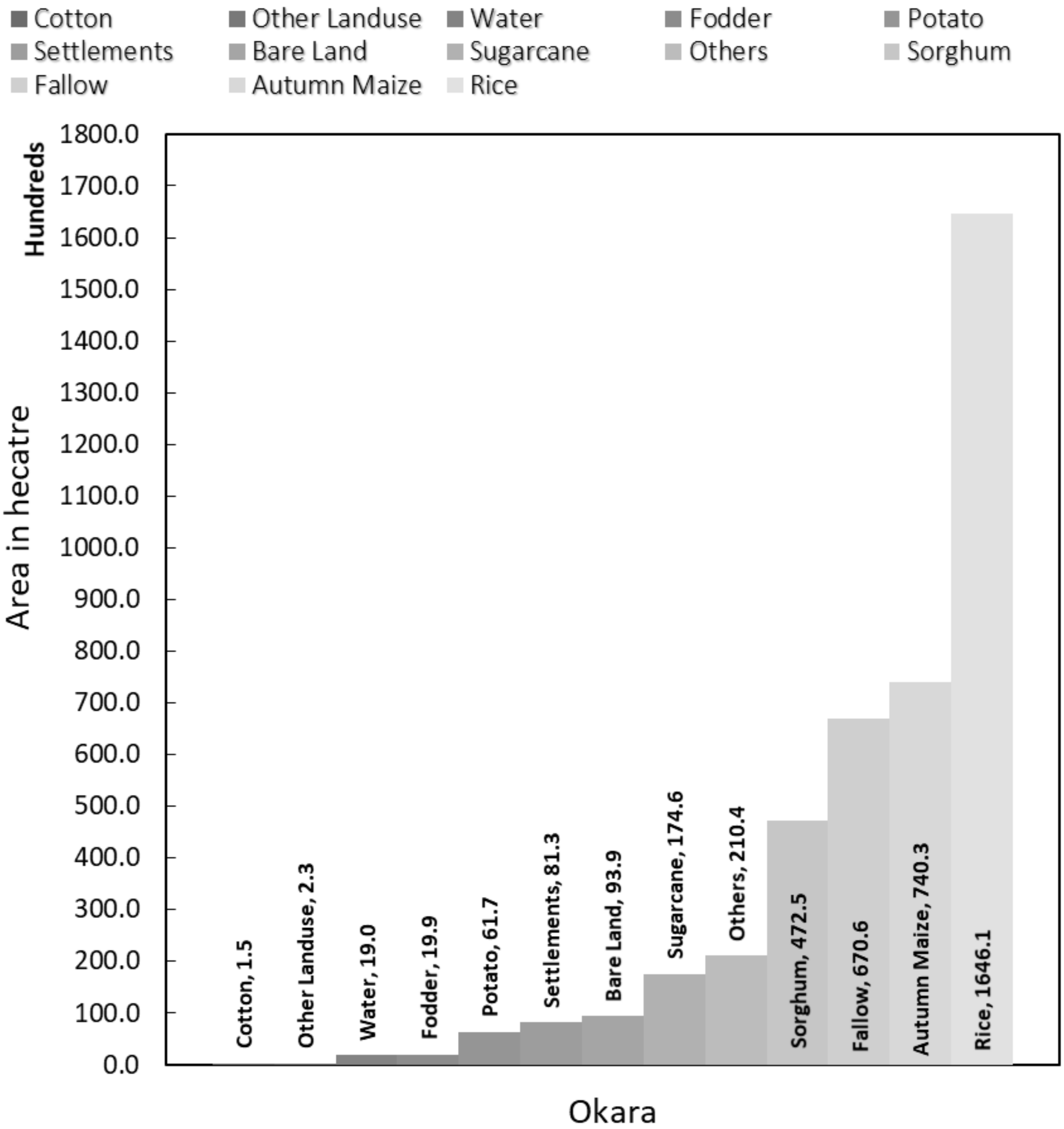

Fig. 7: Spatial Land utilization statistics and its distribution.

4. Discussion

Scope of this research study was to demonstrate the effective use of satellite technology in timely provision of crops cultivated area information within growing season and additionally to establish the land use land cover data for improved land use policy. A detailed ground survey was conducted to collect spatial crop field's information at the end of September, 2017. This information was converted into a spatial database and used for the satellite data image processing.

Major crops and well other land features were spatial mapped and quantified from satellite data in term of cultivated area for Okara district. Rice crop was found as dominated representing around 39.0 % (164614 ha) followed by autumn maize 17.5% (74027 ha), sorghum 11.2% (47247 ha) and sugarcane 4.1% (17456 ha).

Some of the advantages related to satellite based monitoring system recorded in research study are (a) whole spatial coverage of an area as compared to sample based area (b) Reliable crops information availability with least data manipulation (c) Timeliness in availability of crop information as compared to conventional system which become available after 3-6 months of crops harvesting and (d) Improved resources planning and decision making.

Whereas, following are the recommendation for the effective ground survey campaign (a) capacity building of the field surveyors (b) availability of wireless internet devices (c) high accuracy surveying DGPS (d) high quality camera for the field views and (e) above all, trust in use of satellite based technology to make it adoptable.

5. Conclusion

Current study has successfully demonstrated effectiveness of satellite data integration to existing crops reporting system and agricultural land utilization by adding spatial aspect as well as reliability. Furthermore, integration of ground truth survey information with seasonal satellite multi temporal data mad possible the mapping of remote areas which are not accessible due to

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security issues or not including in sample areas for traditional area frame sampling system placed at crops reporting services department. We recommend this technique for further evaluation in other districts and adoption to provide valuable information for effective policy making.

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