Pakistan Geographical Review, Vol.77, No. 2, December. 2022, PP 158-173

CROP IDENTIFICATION FOR RABI AND KHARIF SEASONS USING SPATIO-TEMPORAL TECHNIQUES IN OKARA DISTRICT

MUHAMMAD KHURRAM SHEHZAD[1*] • ADNAN GULZAR[1] • MUHAMMAD ASIF JAVED[1] • SAJID RASHID AHMAD[1]

[1]College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan

*Corresponding author's e-mail: khuram4024@gmail.com

ABSTRACT

Pakistan is an agricultural country and most of country's economic activities directly or indirectly connected to agricultural dealings. Being an agricultural country, there is immense need to enhance agriculture productions to satisfy food and economic needs. Crop identification and quantification is a crucial function in planning for food security of country's population. Modernization in remote sensing and Geographical information system (GIS) techniques opens the new horizons to efficiently monitor the cropping practices and management. Current research has been conducted in Okara district; Punjab province considered potentially sound for agriculture practices freely available open-source Remote sensing data of Sentinel-11 with a resolution of 10 meters has been employed to achieve the objectives of the study. Normalized difference vegetation Index (NDVI) based approach has been incorporated to quantify and map the cropping patterns in study region. Based on season wise (Rabi and Kharif) locally established crop calendar and NDVI based Crop phenology reported with percentage share of various crops in Okara district. Results of the study revealed that wheat, autumn maize, potato are reported as major crops for the Rabi season with 51%, 17.2% and 17% share respectively. Similarly, for Kharif season, rice (38%), Spring maize (15%), and Cotton (7%) were reported major crops. While sugarcane being an annual crop resulted as 4th major crop for both Rabi and Kharif season. Fodder, orchards, tree plantation, bare soil and urban and rural settlements were also quantified in results. Results of the study further verified with the ground survey and Punjab Bureau of Statistics report. This research evident the significance of open-source Remote sensing data in efficiently mapping and quantifying the crop cover with the advantage of cost and time- effective solution.

KEYWORDS: Agriculture, Crop Quantification, Remote Sensing, Normalized Difference Vegetation Index, Crop Phonology.

1. INTRODUCTION

After independence, an opinion-based survey was conducted to get the agricultural statistics in Pakistan in 1947. Objectives of these surveys were to get some estimates which may act as base for agriculture policy decision in order to manage food security issues and natural resources. At the time of independence, irrigated agricultural land was around 10.75 million hectares which has been upraised upto 18 million ha ((Qureshi and Perry, 2021). Being a predominantly agricultural country, in Pakistan about 20.7 million people dependent on the irrigation network developed during the British rule over the sub-continent. However few amendments have been made in this system so far with the additions of two major Dams i.e., Tarbela and Mangla along with link canals. Agriculture being a largest economic industry in Pakistan, almost 67%population is directly or indirectly involved in agricultural activities (Zafar& Waqar, 2014). In Pakistan, around 22 million hectare is cultivable, while 8.3 million hectares is non-cultivated out of total area of 79.6 million ha. However, forests constitute around 4.21 million hectares (Azam & Shafique, 2017).

There are very huge gaps in the existing agriculture statistics; almost statistics are lag by three to four months after crop harvesting which results in irrational decision making. However, the decision making on import and export of agricultural produces is also influenced by the political and private sectors. It’s the time to revamp these obsolete monitoring practices (Akhtar, 2012). Therefore, it is inevitable to develop a system with better monitoring capabilities to provide reliable timely information about crop status. This system must be capable enough to provide yield forecast in any region of the country as well (Lu et al., 2022). Satellite based earth observation data is quite effective to fulfill this objective as it provides accurate, consistent and timely information about the agricultural productivity at local and regional scales (Maimaitijiang *et al.,* 2020; Whitcraft *et al.,* 2015). Remote sensing based Landuse landcover mapping and acreage estimation proved to be quite effective and efficient with the advancement and availability of high-resolution imagery (Durgun *et al*., 2016; Waldhoff *et al*., 2017; *Nguyen et al*., 2020). Furthermore, temporal availability of these products makes the assessment and measurement of crops at different intervals, different stages and monitoring of crop health across the entire season played a very vital role for planners and decision makers. In addition, these technologies are of grave importance for the countries facing food security issues (Waldhoff *et al.,* 2017; Xiong, 2014; Hussain, 2018). In, 1972 Landsat mission provided the world an invaluable archive of imagery at 16-day time interval which provided unprecedented estimates of crop cover mapping, crop area extraction and information about crop stages (Whitcraft, 2015). This information served as indicators for the agricultural productivity of any region (Supavetch, 2018).

1.1. Study Area

Our selected district for crop yield estimation Okara is well-known for its productive lands, peaceful natural atmosphere and green fields of sugarcane, tomato, potato, maize crops, rice and wheat. Common orchards are mangoes and oranges. Old and non-precise ways of estimating crop yields are one of the major hurdles in agriculture sector's efficiency. This research provides the solutions based on freely available open-source Remote sensing data in efficiently quantifying the cropping practices in Okara district. This research will provide the basis for agriculture or relevant departments to develop and implement a decision support system based on Open-source datasets. Moreover, Output of this system will provide the estimates of crop production for specific areas, and it will help in updating of the data related to demand, Consumption and Production matters. To achieve higher production values by estimating or analyzing them on growth stages and before harvest period. This research aimed at to achieve the following objectives; i) NDVI calculation to differentiate the vegetation cover or crops distribution in Okara district, ii) establishing the crop phenology in order to efficiently identify the crops, ii)

2. MATERIAL AND METHODS

The Okara district selected for this study is located in the Punjab province of Pakistan. The east border of the district is surrounded by the India, south part shared the boundary with Bahawalnagar and Pakpattan, on the North there is Kasur district and the West border is shared with Sahiwal, Sheikhupura, and Faisalabad districts. The district covered an area of 4119 km^2 with the geographical from 30.258°N, 73.272°E to 31.131°N, 74.211°E.

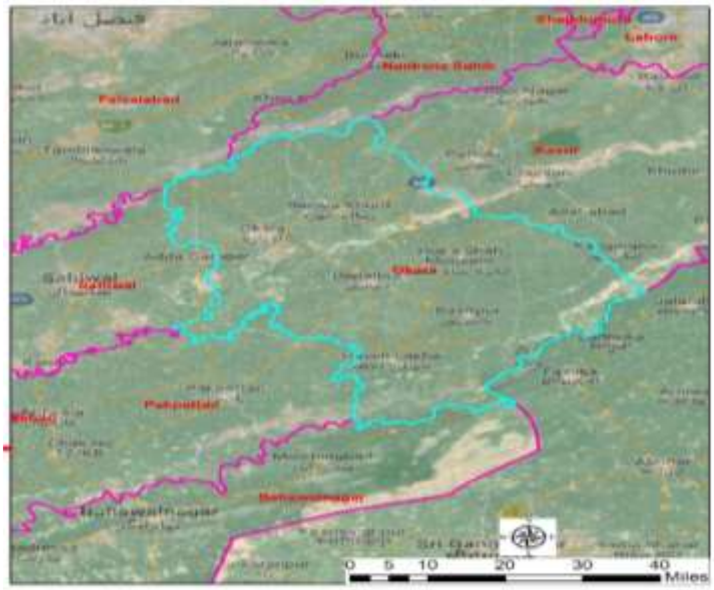

Fig. 1. Location Map of Study Area

Multispectral images have been used to identify crop varieties and crop phonology. For the study, Sentinel imagery acquired/downloaded from the link; https://scihub.copernicus.eu/. To cover the Rabi and Kharif season, Imagery is downloaded from (May 2018 to May 2019). Crop calendar is acquired from the Department of Agriculture, Lahore and validated from the formers while the data collection from field.

Table 1. District Okara Crop Calendar

CROP Type	JAN	FEB	MAR	ARP	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WHEAT												
POTATO												
MAIZE (Spring)												
MAIZE (Autumn)												
FODDER												
RICE												
COTTON												
SUGARCANE												

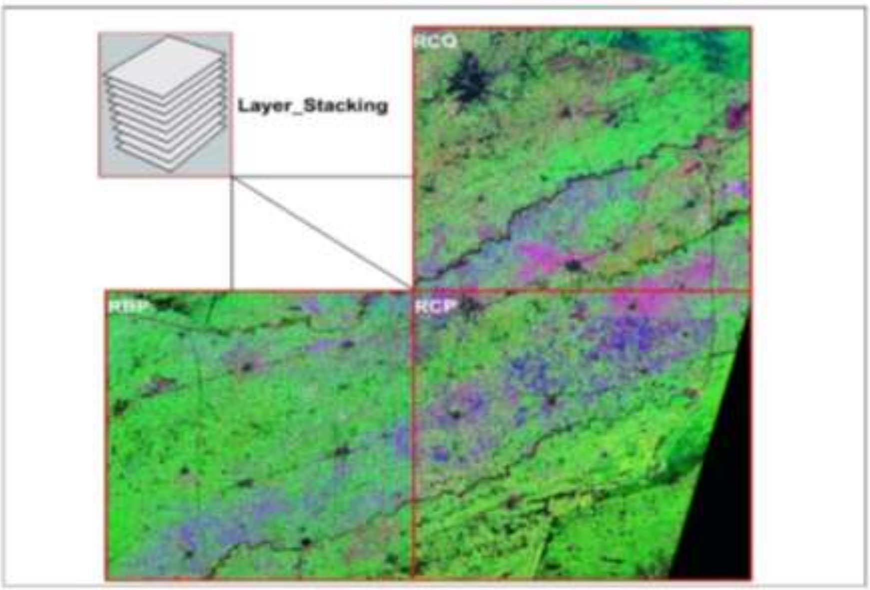

Fig. 2. NDVI Stacking

Normalized difference vegetation index (NDVI) is being used in this study to extract the crop cover in study area. As NDVI is the best suitable index and globally recognized to delineate the vegetative cover in any area. Therefore, on the NDVI data, unsupervised classification technique has been applied using ISO data model. The ISO data randomized ranking algorithm was performed on 10-day NDVI time series data to create base maps. This process provides an understanding of the specific color-temporal classes or clusters and their relatively landscaping positions in the multidimensional NDVI stack. The groups resulted from the classification are spectral classes, because they are based entirely on normal clusters in image values. For the accuracy assessment of the data, the analyst must have some reference data. In this research we have used the crop calendar developed by the agriculture department along with the verification from the formers during the field visit. ISODATA is one of the well-known clustering techniques which is used in remote sensing. Among the different methods of unsupervised classification ISODATA is the one which is commonly used. ISODATA clustering algorithms are repetitive in nature because they first choice arbitrary early values that reflect the features of the cluster and greatly influence the classification process.

By deleting, merging, and splitting clusters, the algorithm allows the clusters to variation from one reiteration to the next. Typically, this algorithm first assigns a random initial cluster vector following by the classification of each pixel into the nearest cluster. Then the third step in which the new cluster refers to the vector is calculated based on all the pixels in a cluster. There is the repetition of the 2nd and 3rd steps unless the “change” is small between the iteration. This "change" can be explained in a variety of ways, also by shrewd the distances and altering the meaning of the cluster vector from one repetition to another or by the proportion of pixels that have alter demon iterations.

On the NDVI stacked Images, unsupervised classification is successfully applied for the major crops in the study area. The fundamental process of classification was performed in Erdas Imagine software (specialized for image classification and analysis) by plotting the NDVI curve on the resultant classified Image. At this stage, the combination of bands on the stack image of the respective graded image aided to identify specific classes based on NDVI pattern of specific crops. Band combination shows the band one is for the sowing time, the second /middle band shown the peak stage, and the 3rd band is showing the harvesting time of the respective crop. These entire bands have the NDVI values with them (Zafar, 2014; Iuh, 2018).

Normalized Difference Vegetation Index (NDVI) is calculated for every crop by using the different location in this study and then compares the dates of the mapped images of these NDVI curve values, from which the NDVI was calculated. The resulting NDVI curve in contradiction of every crop shadowed the pattern of the particular crops.

2.1. Field Survey/ Results Validation

Global positing system (GPS) based field survey was conducted in both Rabi and Kharif seasons to verify the classification results. More than 35 random field samples covering all crops across the study region were collected to determine the results accuracy. Moreover, Results of crops quantification were also compared with the Punjab development Statics, report published by Bureau of statistics Punjab annually.

3. RESULTS AND DISCUSSION

The results are divided into three parts, one is phonology-based profiles creation and analysis as per the growing season of Rabi and Kharif crops, second is mapping of crop type, and the third is accuracy assessment by using the field data. The resultant profile of the NDVI phonology of one year shows two main seasons of crop Rabi and Kharif in the study area.

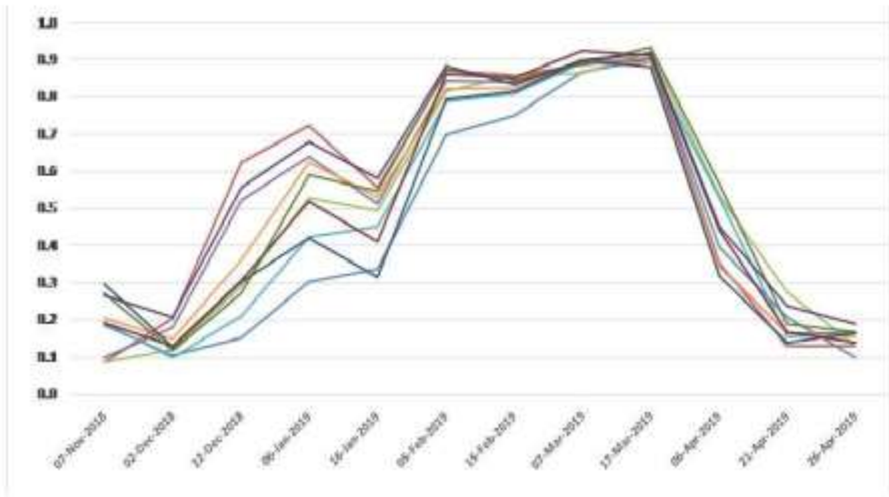

Fig. 3. Phonological profile of wheat Crop

Figure 3 illustrates the different stages of the wheat crop with sowing starting in the month of November and being harvested in the month of April. NDVI based phonology depicting that reflectance values are low in the month of November,

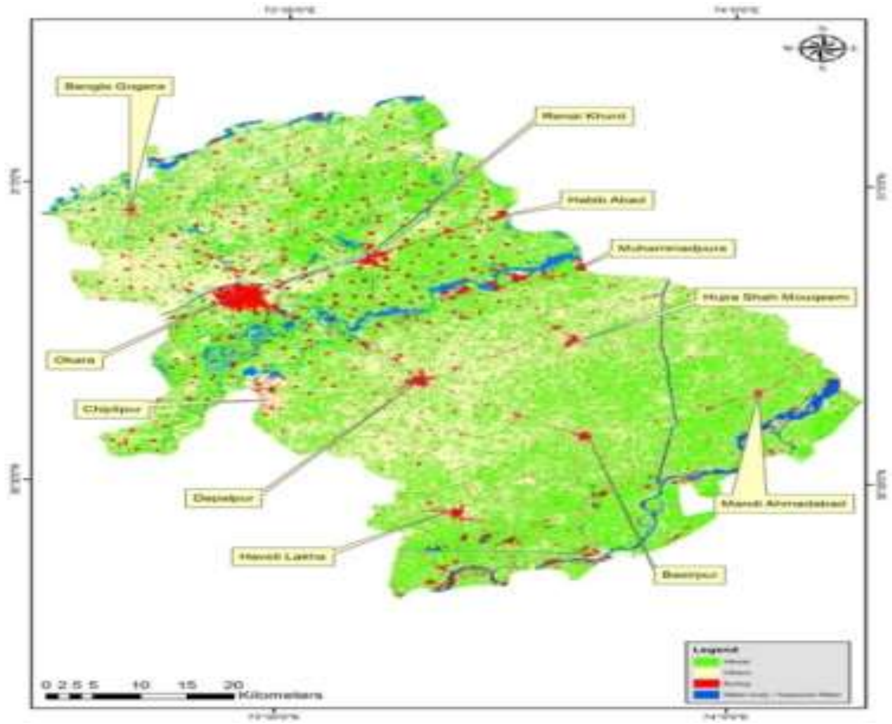

Fig. 4. Spatial Distribution profile of wheat Crop

Where wheat crop is at its initial stage, however it attains peak in the months of February and March, at middle stage of the crop. Spatial distribution pattern depicting that wheat crop has high dominating (around 51 %) over all the other crops in Okara district (Figure 4)

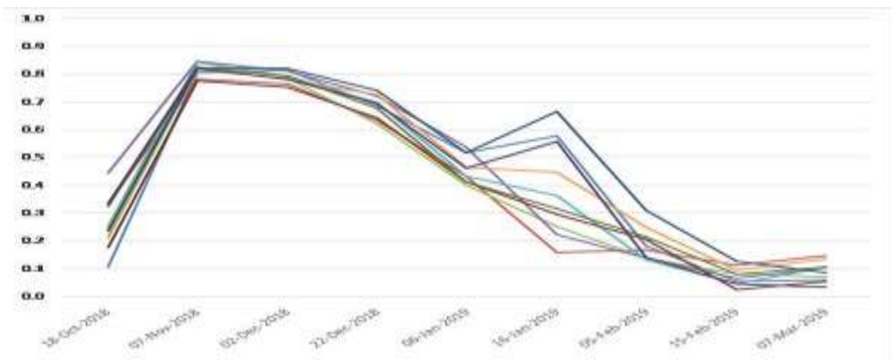

Fig. 5. Phonological Profile of potato Crop

Some pockets in central parts of the district observed with the cultivation of other crops. However, autumn maize and potato crops are observed with the second and third largest share in study area. Phonological profile of potato crop showing that cultivation of this crop starts in the month of October and being harvested in the month of March. Potato crop reflects maximum value in the month of November and December at its middle stage; however, the reflectance value starts goes down from the month of January. Samples of potato crop collected from entire study region depicting more or less same behavior of all NDVI's (Figure 5)

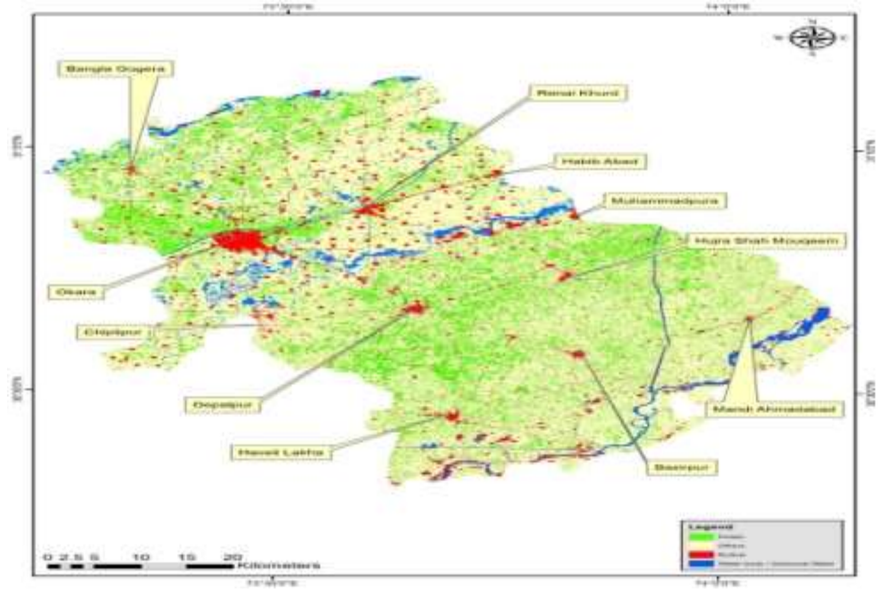

Fig .6. Spatial Distribution Profile of potato Crop

Some pockets in north-east and north-west are observed with the cultivation of the potato crop; however, central region of the Okara district is highly enriched with potato cultivation. Okara district is considered among the districts having significant share in potato production, and in our results percentage share of 17% observed (Figure 6).

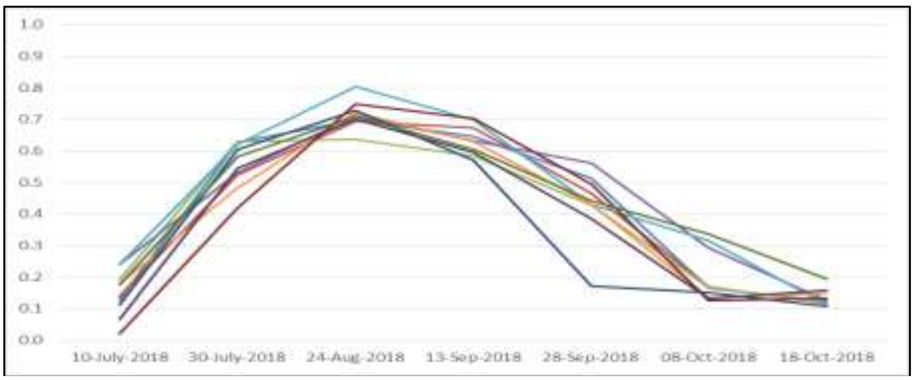

Fig.7. Phonological& Spatial Distribution Profile of Rice Crop

Kharif season in Okara district has almost stretch from May mid to October Mid. rice, cotton and spring maize have observed major crops for the Kharif Season. Cultivation of rice crop starts at the end of June in Okara and continue until mid of July, while rice crop reaches to its middle stage at the end of August where it reflects maximum value i.e., 0.8. At end of September reflectance starts goes down and it's harvesting stats at the start of October (Figure 7).

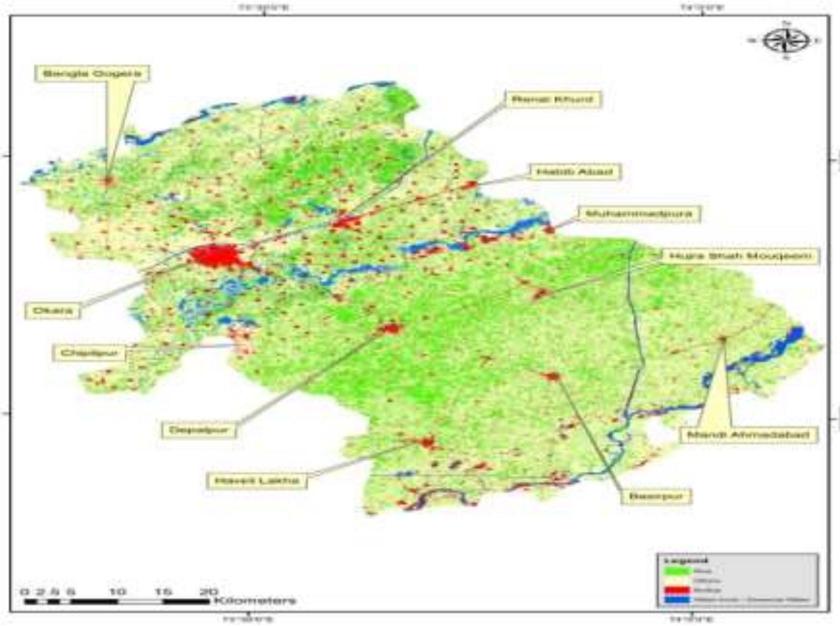

Fig. 8. Spatial Distribution Profile of Rice Crop

Spatial distribution pattern of the Rice crop in the study region depicts resulted with the high density around the Renala Khurd, Habibabad, Depalpur and Hujra shah Muqeem cities. Around 37 % share of Rice crop has been observed in Rabi crops (Figure 8)

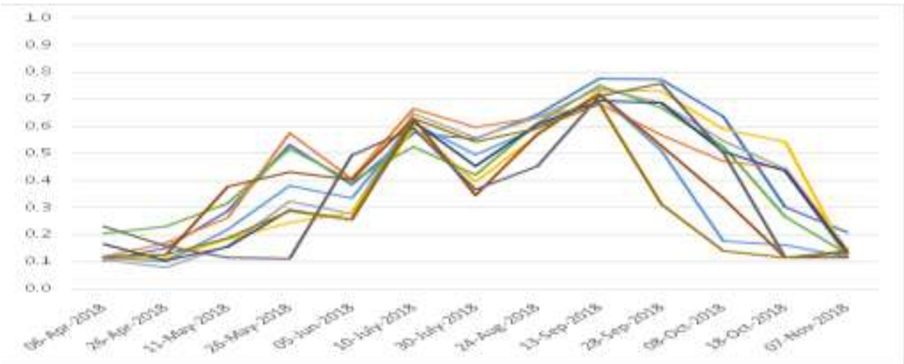

Fig.9. Phonological Profile of Cotton Crop

Cotton crop sowing and cultivation ranges between April-November in study region with maximum reflectance in the month September i.e., 0.78. Phenology profile of cotton crop showing the different stages i.e., initial

(April), middle (July & August) and final stage (October) where cultivation of this crop started (Figure 9).

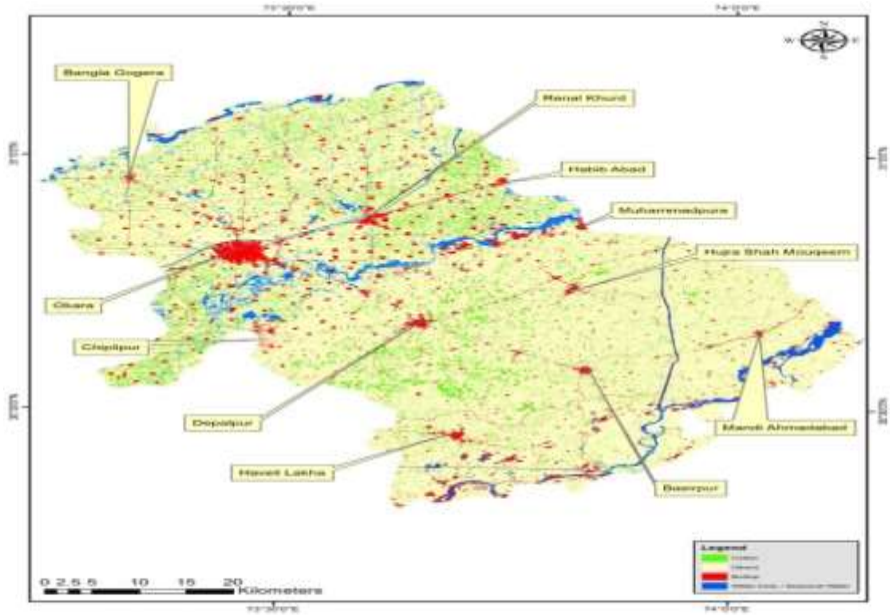

Fig.10. Spatial Distribution Profile of Cotton Crop

Some dispersed cultivation of cotton crop around Okara and Renal Khurd cities has been observed in the spatial distribution mapping. However, some pockets of cotton crop have also been identified around Depalpur city. Around 7% share of cotton crop has been observed as per classification results (Figure 10).

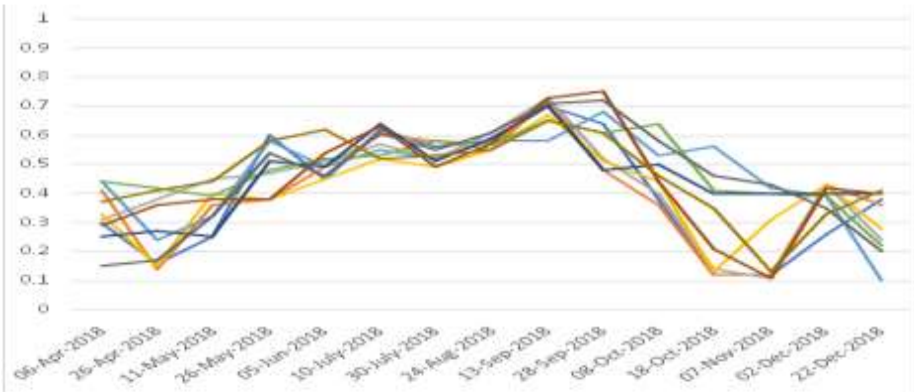

Fig.11. Phonological Profile of Sugarcane Crop

Sugarcane is the annual crop; sowing starts in the month of March/ April and harvesting in December/ January in study region. It reflects maximum values (i.e., 0.73) in the month of August and September at middle stage.

Initial, Middle and final stages of the sugarcane have been illustrated by phonological profile. In classification results, sugarcane is observed with 4th largest share for both Rabi and Kharif season crops (Figure 11).

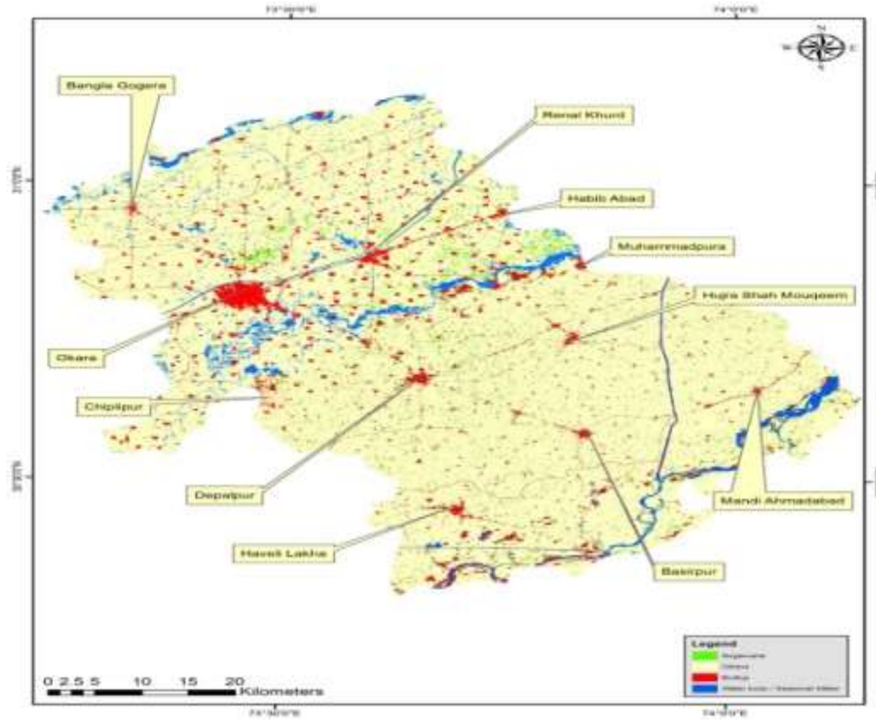

Fig.12. Spatial Distribution Profile of Sugarcane Crop

Spatial distribution mapping of the sugarcane crop highlights that clustering of this crop near Okara, Muhammadpura and Habibabad. However, small pockets are also observed near Dipalpur city with dispersion in smaller chunks across the whole study area (Figure 12).

Composite spatial distribution of all the major crops identified in Rabi and Kharif seasons in Okara district has been illustrated in Figure 13for Rabi season, it is clearly seen that Wheat has the largest share and concentration following with the Autumn Maize and Potato crops. High density of Potato crop is observed in northern regions of the district, with some pockets in middle parts near Depalpur. Similarly, Autumn Maize which has 2nd largest share, a slightly higher than potato i.e., 17.2 % in Rabi crops has also been observed with the same pattern of Potato crop. Figure13 also depicting the spatial distribution of the Sugarcane, orchards and Fodder observed in Rabi season.

However, very less concentration of observe Bare soil has also been depicted in the results (Javed and Sajid, 2020). Figure 14 showing rice is the major crop for Kharif season following by the spring maize and cotton.

Rice cultivation is dominating over all crops around with 38% share. High concentration of rice is observed in southern regions of the district. High concentration of spring maize is existing in the northern parts of the district as compared to southern regions. In contrary, cotton has high density in southern parts, specifically near Depalpur city (Javed *et al*., 2010; Javed and Sajid, 2020).

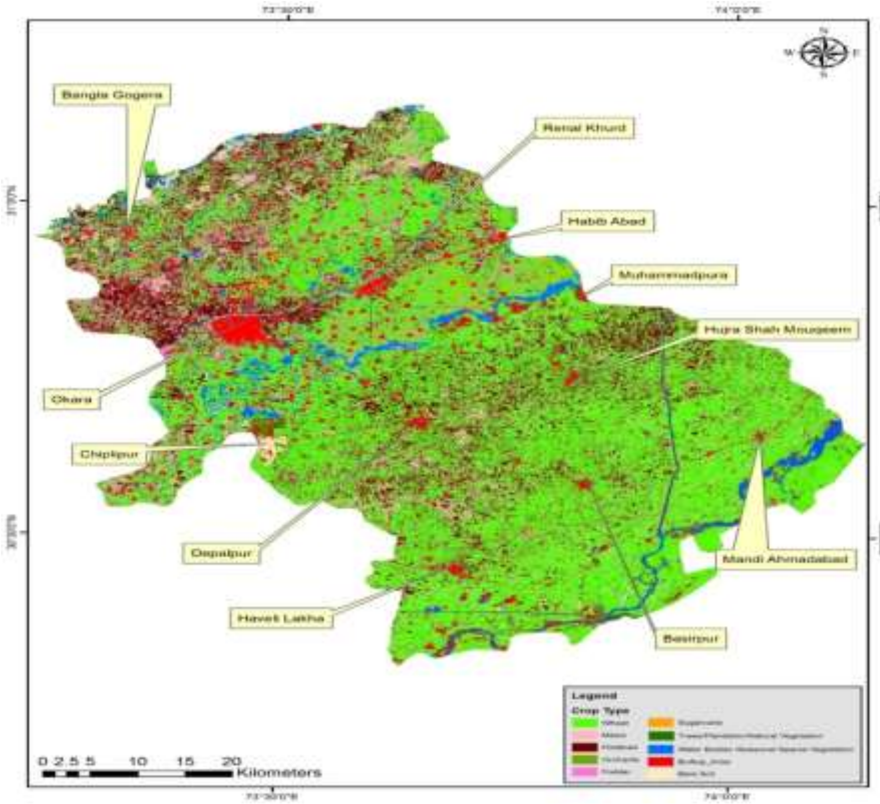

Fig. 13. Map showing Crop Classification for Rabi season

In order to verify the classification results, GPS based field survey has been conducted in order to check how much crop classification is accurate. Survey was planned in such a way that both Rabi and Kharif crops must be covered. So, the months of February and August of the year 2020were selected to validate the results as almost both Rabi and Kharif crops exist at their middle stages in these months. Around 35 samples for each season were taken across the whole district in such a way that all major crops must be covered in this survey. Figure15, showing the ground validation locations across the whole study region.

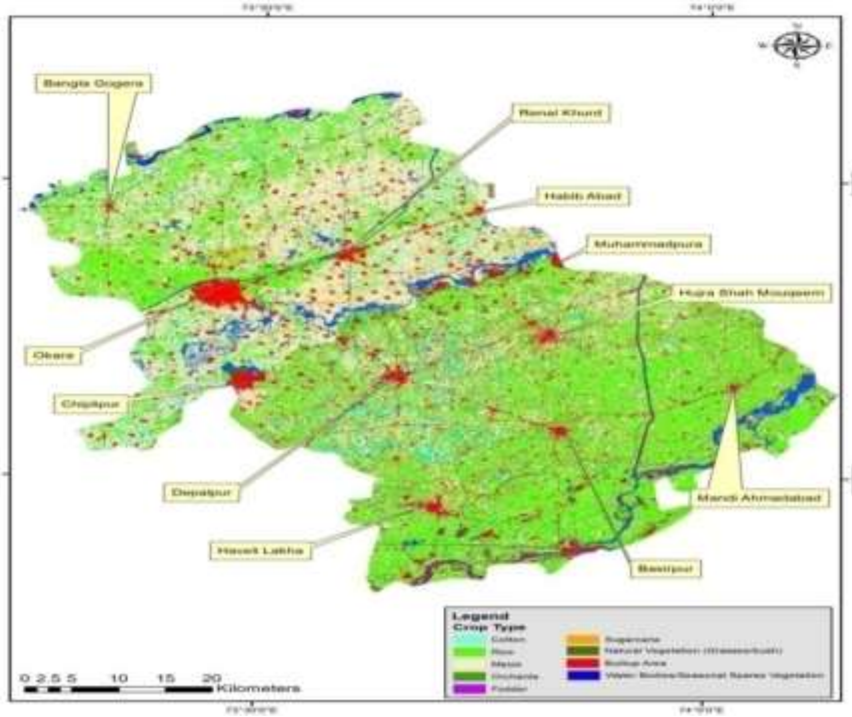

Fig. 14. Map showing Crop Classification for Kharif Season

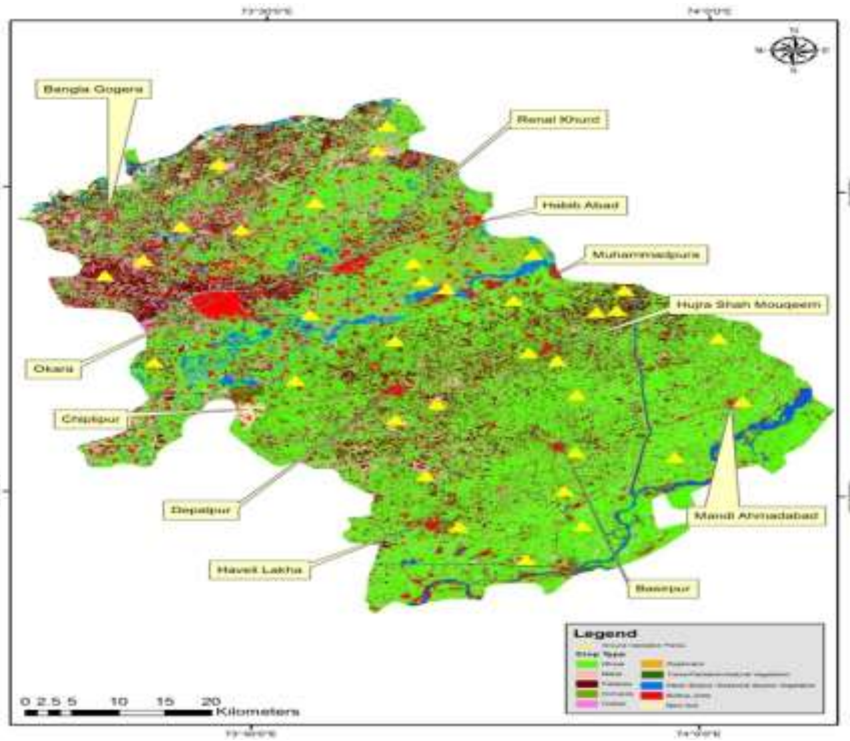

Fig. 15. Ground Validation

Moreover, classification based calculated quantities of each major crop in the Okara district was compared with report of Bureau of Statistics; Punjab Development Statistics published each year. Comparison shows the differences between PDS estimated quantities and our classification-based quantities. As the PDS Values are not 100 % accurate as they also have some assumption/ estimations in their quantification. Furthermore, classification-based quantification also has some limitations in crop cover mapping due to the resolution factor of satellite sensor (10m).

Table 2: Comparison of Classification Results with bureau of Statistics, Punjab

Rabi Crops			Kharif Crops		
Crop	**Classification Area (Acres)**	**PDS Statistics (Acres)**	**Crop**	**Classification Area (Acres)**	**PDS Statistics (Acres)**
Wheat	533500	499000	**Rice**	385010	355000
Autumn Maize	175025	195000	**Spring Maize**	155540	150000
Potato	173205	143315	**Cotton**	69189	67000
Sugarcane	37518	36000	**Sugarcane**	37518	36000
Others	133384	179317	**Others**	405375	444632
Total Area	1052632	1052632	**Total Area**	1052632	1052632

4. CONCLUSIONS

In this research NDVI based-crop health phonology method has been employed to quantify and map the different crop covers in Okara district, freely available high-resolution Sentinel-II imagery with 10metre resolution being utilized to achieve the objectives of the study. Adopted methodology is experimented, widely accepted and in practice in many studies across the globe for similar studies. This research based on freely available open-source data proved to be quite effective in crop cover mapping, crops identification, quantification and thus yield estimation. This methodology also evident that remote sensing-based techniques provides time and cost based efficient solutions. By practicing this approach effective policy and decision making can be made regarding crop production and demand; thus, supply and demand analysis can be performed and subsequently import and export policy making may be done on right time. Inclusion of spectroradiometer will lead to draw the spectral signature of each crop more precisely which will result in improving the accuracy of study to a higher extent. Similar studies must be conducted on provincial or country level which will be helpful in improving irrigation management and updation of agro-ecological zones as well.

REFERENCES

Akhtar, I. U. H. (2012). Pakistan needs a new crop forecasting system.

Azam, A., and Shafique, M. (2017). Agriculture in Pakistan and its Impact on Economy—A

calendar over Okara District, Punjab (Pakistan). *Journal of Space technology*, 4(1), 3-7.

Durgun, Y. Ö., Gobin, A., Van De Kerchove, R., and Tychon, B. (2016). Crop area mapping using 100-m Proba-V time series. *Remote Sensing*, 8(7), 585.

Hussain, A., Javed, K., and Ghazanfar, H. (2018). Multi-Temporal Landsat8 Satellite Data Based Crops and Other Land Use Spatial Estimation in Okara District of Pakistan. Initiative (GEOGLAM). Remote Sensing, 7(2), 1461-1481

IuH, A., Hussain, A., Javed, K., & Ghazanfar, H. (2018). Landsat8 Based Crops and Other Land Use Mapping in Okara District of Pakistan.

Javed, M. A., & Ahmad, S. R. (2020). A Decision Support System for Crop Water Requirement Estimation Using Advanced Geospatial Techniques. Pak. J. Agri. Sci, 57(4), 981-991.

Lu, Y., Liu, M., Li, C., Liu, X., Cao, C., Li, X., & Kan, Z. (2022). Precision Fertilization and Irrigation: Progress and Applications. AgriEngineering, 4(3), 626-655.

M., Sagan, V., Sidike, P., Daloye, A. M., Erkbol, H., and Fritschi, F. B. (2020). Crop monitoring using satellite/UAV data fusion and machine learning. Remote Sensing, 12(9), 1357.

Qureshi, A. S., & Perry, C. (2021). Managing water and salt for sustainable agriculture in the Indus Basin of Pakistan. Sustainability, 13(9), 5303.

Supavetch, S. (2019). Sentinel-2 based Remote Evaluation System for a Harvest Monitoring of Sugarcane Area in the Northeast Thailand Contract Farming. In *GISTAM* (pp. 234-241).

Maimaitijiang, M., Sagan, V., Sidike, P., Daloye, A. M., Erkbol, H., & Fritschi, F. B. (2020). Crop Monitoring Using Satellite/UAV Data Fusion and Machine Learning.Remote Sensing, 12(9), 1357.

Nguyen, H. T. T., Doan, T. M., Tomppo, E., and McRoberts, R. E. (2020). Land Use/land cover mapping using multitemporal Sentinel-2 imagery and four classification methods—A case study from Dak Nong, Vietnam. *Remote Sensing*, *12*(9), 1367.

Waldhoff, G., Lussem, U., and Bareth, G. (2017). Multi-Data Approach for remote sensing-based regional crop rotation mapping: A case study for the Rur catchment, Germany. *International journal of applied earth observation and geoinformation*, *61*, 55-69.

Whelen, T., and Siqueira, P. (2018). Time-series classification of Sentinel-1 agricultural data over North Dakota. *Remote sensing letters*, *9*(5), 411-420.

Whitcraft, A. K., Becker-Reshef, I., and Justice, C. O. (2015). A framework for defining spatially explicit earth observation requirements for a global agricultural monitoring initiative (GEOGLAM). *Remote* Sensing, 7(2), 1461-1481.

Xiong, D. (2014). Crop growth remote sensing monitoring and its application. Sensors & Transducers, 169(4), 174.

Zafar, S., and Waqar, M. M. (2014). Crop type mapping by integrating satellite data and crop calendar over Okara District, Punjab (Pakistan). Journal of Space technology, 4(1), 3-7.