OPEN ACCESS International Journal of Agriculture and Sustainable Development.

50SEA.COM

IJASD ISSN:2618-1193

Estimation of Wheat Area using Sentinel-1 and Sentinel-2 datasets (A Comparative Analysis).

Ayesha Behzad[1], Muneeb Aamir[1], Syed Ahmed Raza[1], Ansab Qaiser[1], Syeda Yuman Fatima[1], Awais Karamat, Syed Amer Mahmood

[1] Department of Space Science University of the Punjab Lahore, Pakistan.

* Correspondence: Ayesha Behzad E-mail : ayshabehzad9876@gmail.com
Citation | Behzad. A, Aamir. M, Raza.S.A, Qaiser.A, Fatima.Y.S, Karamat.A, Mahmood. S. A". Estimation of Wheat Area using Sentinel-1 and Sentinel-2 datasets. International Journal of Agriculture and Sustainable Development, Vol 01 Issue 03: pp 81-93, 2019.
DOI | https://doi.org/10.33411/IJASD/2019010306
Received | May 04, 2019; Revised |June 07, 2019 Accepted | June 08, 2019; Published | June 11, 2019.

Abstract
Wheat is the basic staple food, largely grown, widely used and highly demanded. It is used in multiple food products which are served as fundamental constituent to human body. Various regional economies are partially or fully dependent upon wheat production. Estimation of wheat area is essential to predict its contribution in regional economy. This study presents a comparative analysis of optical and active imagery for estimation of area under wheat cultivation. Sentinel-1 data was downloaded in Ground Range Detection (GRD) format and applied the Random Forest Classification using Sentinel Application Platform (SNAP) tools. We obtained a Sentinel-2 image for the month of March and applied supervised classification in Erdas Imagine 14. The random forest classification results of Sentinel-1 show that the total area under investigation was 1089 km^2 which was further subdivided in three classes including wheat (551km^2), built-up (450 km^2) and the water body (89 km^2). Supervised classification results of Sentinel-2 data show that the area under wheat crop was 510 km^2, however the built-up and waterbody were 477 km^2, 102 km^2 respectively. The integrated map of Sentinel-1 and Sentinel-2 show that the area under wheat was 531 km^2 and the other features including water body and the built-up area were 95 km^2 and 463 km^2 respectively. We applied a Kappa coefficient to Sentinel-2, Sentinel-1 and Integrated Maps and found an accuracy of 71%, 78% and 85% respectively. We found that remotely sensed algorithms of classifications are reliable for future predictions.

Keywords: Sentinel-1, Sentinel-2, Yield-Area Index, Kappa Stat, Random Forest Classification.

Introduction

The global agriculture will be dramatically influenced by various factors including the population growth, biofuel consumption, dairy and meat demands. These burdens are projected to face in future, because many researchers have reported yield stagnation in various cereal crops including rice, wheat and maize etc. The global food demand is expected to get doubled by 2050 [1,2,3]. The global crop production was enhanced by 28% during 1985 to 2005 by an increase in 7% in crop land area [4]. The recent global crop production was short of the expected demands which left a question for us: which topography is suitable for which region that may offer mouthful production to fulfill the needs of increasing population. Yield stagnation for various cereal crops was reported by many researchers around the world [5,6,7,8,9,10]. This stagnation was particular for three major crops including rice, wheat and maize which together contribute about 57% of global calories available for humans [2].

The world's population is projected to cross the figure of 9.3 billion by 2050. Pakistan is among the countries having high population growth which is expected to be 300 million by 2050. Basic needs of life like food, shelter, cloth and other necessities of life are required to cater the basic needs of this population.

Agriculture sector has employed about 43% of rural population and contributes 21% in Gross Domestics Product (GDP) of Pakistan. The contribution of major crops like wheat, maize, rice, sugarcane and cotton in value addition is 25.6%. The life cycle of wheat crop is dependent upon the environmental conditions in which the wheat is grown. Wheat crop growth stages are important to determine the electromagnetic responses of crop growth elements. Sensor configuration like frequency, polarization and incidence angle need high expertise for evaluation of various plant level characteristics like plant biomass, soil moisture, crop canopy structure, leaf size and stem elongation [11, 12,13]. The leaves of wheat crop are oriented vertically therefore, the backscatter decreases with increase in incident angle.

Appraisal of crop monitoring in various growth stages and the yield estimation are important to determine for sustainable development. High resolution satellite imagery seems to be an attractive approach to investigate spatio-temporal responses of crop growth [13]. The growth parameters are useful for monitoring of crop development in each stage that determine the possible crop production.

Ground based radars emerged in 1970, that obtained high attraction and publicity due to their efficient use in various agricultural applications [14,15]. These ground-based instruments were mounted on satellites to monitor topographic events from space. Synthetic Aperture Radar (SAR) is an active sensor which transmit and receive signals in microwave frequency. Many researchers have used SAR data to monitor various crops like wheat [16,17] rice [18,19,20] Sunflower [21], Soybean [22] and Corn [23]. SAR data is preferred in agricultural applications because it is not affected by atmospheric conditions therefore, we get consistent temporal responses of high resolution.

Sentinel-2 is a project of Copernicus program that offer the ground observations in optical ranges. The level-1 product of Sentinel-2 is highly cost effective and geometrically correct. The collaborative study of Sentinel-1 and Sentinel-2 datasets provide highly accurate classification results.

This study presents a comparison of Sentinel-1 and Sentinel-2 datasets to compute the winter wheat area. It also aims at collaboration of both active and passive sensors to construct a highly accurate map of wheat plantation in the investigation site by integrated impact of Sentinel-1 and Sentinel-2 datasets. A well-known Kappa coefficient is also used for accuracy assessment of supervised classification.

Material and Methods.

Study site.

This research was conducted in Narowal district of Punjab, Pakistan. Narowal is famous for production of export quality rice due to rice friendly eco-physical conditions. Wheat is considered as cash crop which give mouthful profit to locals. The study site is in range of moonson therefore, surplus of rainfall hit this area every year which is a good sign for proper growth and development of rice crop. The spatial extent of study site is mapped in Figure 1 as below,

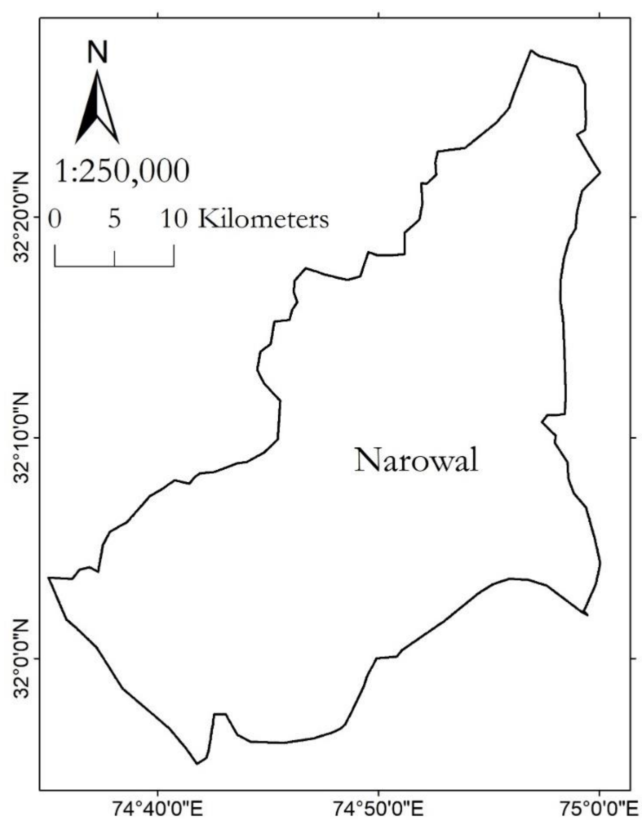

Figure 1. Study site.

Methodology.

The spectral responses of a particular crop are of great importance to analyze biochemical and photo-chemical reactions occurring in plant's body. Many sensors mounted on satellites record the plant's behavior in visible, infrared and microwave ranges of electromagnetic spectrum. Various researchers have used the satellite recorded responses in many plant related applications [24,25] e.g., Yield-Area index, growth and development index and the photosynthesis in plant's body. MODIS datasets with a temporal window of 8 days were used by Gumma et al., 2014 [24] for mapping cropping patterns of rice crop in Bangladesh. MODIS Normalized Difference Vegetation Index (NDVI) dataset were used by Asilo et al., 2014 [25] for mapping of various crops in Ecija province.

We acquired an optical satellite image of Sentinel-2 for the month of March from earthexplorer website (earthexplorer.usgs.gov) to extract the wheat area within study site. We selected this month because the wheat crop has full-fledged growth during the same time in the study site. The climatic events e.g., clouds, winds and others are recorded by the satellites working in optical range which cause to disturb the accuracy and visibility of optical imagery. Active remote sensing is the best solution to get rid of climatic events, which enhances the accuracy and improve the classification results.

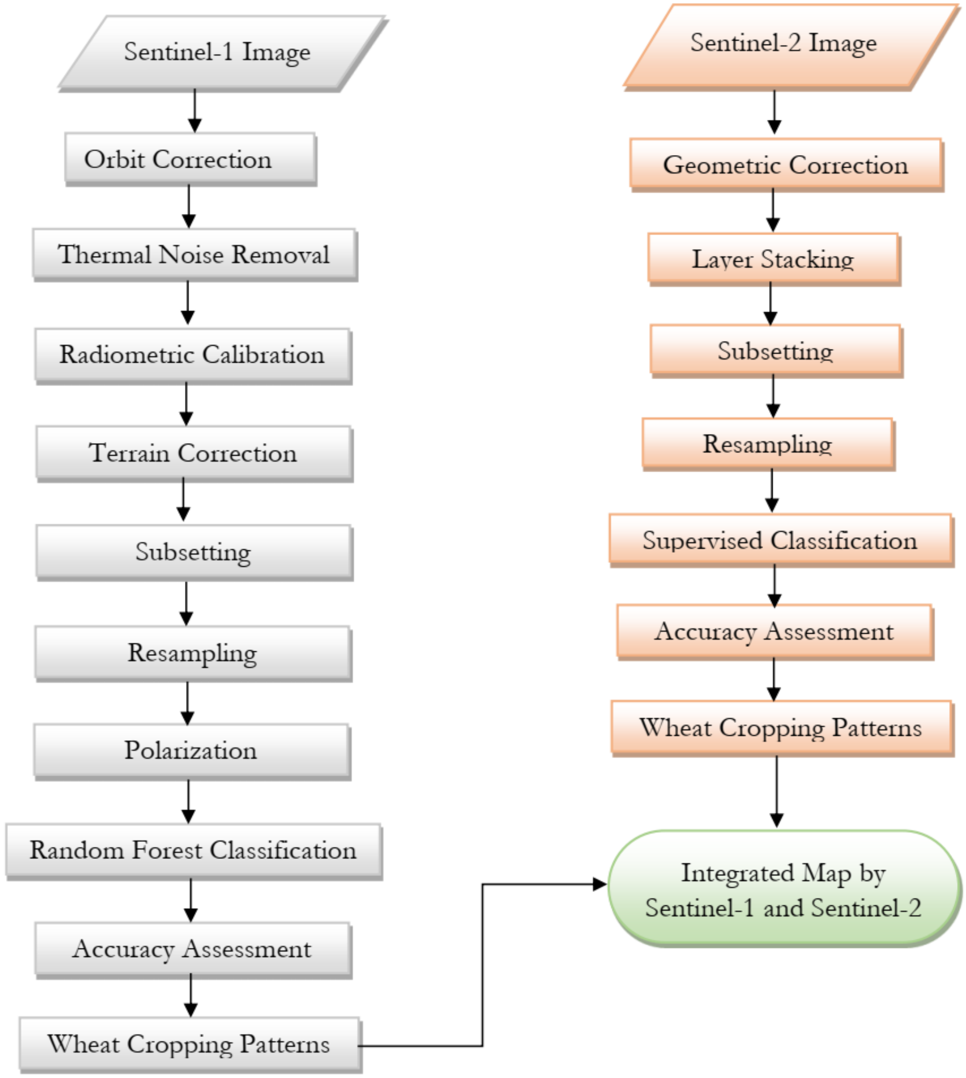

Figure 2. Flow of study.

Active remote sensing is based on microwave signals, where a transmitter mounted on satellite throw a signal toward ground and the ground bounce back it toward the sensor. Sentinel-1 is the project of European Space Agency (ESA) which was launched in space on 03 April 2014 having a spatial resolution of 20m. Sentinel-1 was designed to transmit and receive microwave signals in both vertical and horizontal polarizations. We acquired a Sentinel-1 image from ESA website to map wheat cropping pattern.

We collected the wheat crop field data and the farmer's reviews using Differential Global Positioning System (DGPS). The non-wheat areas such as buildup, trees, bushes and Jowar were demarcated to select wheat crop only.

Sentinel-1 data was downloaded in Ground Range Detection (GRD) format and applied the Sentinel Application Platform (SNAP) tools for data processing. The GRD data was projected by applying an orbit file to perform radiometric and geometric correction. Actually, the orbit file has the information about the velocity and position of the satellite which is corrected online. The geometric corrections present accurate information about the mode, time and sensor of acquisition of a particular SAR image.

Spackles are salty structure in SAR images which are the result of interference of microwave signals that must be removed. LEE filter is commonly used to remove spackles from a SAR images [18]. High temperature causes the microscopic movement of electrons which produce thermal mosaic in SAR images that must be removed to get refined results. The tool "Thermal Noise Removal" in SNAP was applied to obtain noise free images.

A tilt in backscatter created by actual topographic variations in SAR images was removed by terrain correction tool embedded in SNAP. Sentinel-1 data is comprised of $20*20m^2$ boxed which were converted to $10*10m^2$ box. It is called resampling which give efficient and improved results. The only drawback of resampling is the more processing time. The swath width of Sentinel-1 image is $400 *400km^2$ that need more processing time and it is essential to figure out the exact area of interest from the SAR images therefore, we executed sub setting by applying a mask to Sentinel-1 image to extract the investigation site only from a large dataset.

Sentinel-1 data is comprised of two polarization (Vertical-Vertical) and (Vertical Horizontal). These polarizations are good to discriminate the wheat crop in comparison to other crops. We selected some areas as seeds for Random Forest Classification (RFC) to highlight and to differentiate between the existing land use in the study site.

We obtained a Sentinel-2 image for the month of March for further processing. The Sentinel-2 image consists of 12 bands but we selected bands in visible and infrared wavelengths and stacked them using layer stacking utility in Erdas Imagine 14. The stacked image was geometrically analyzed by pointing out major landmarks but could not found any considerable variations. We selected 53 trainee samples and applied the supervised classification in Erdas imagine. The area under investigation was extracted using subset utility in Erdas imagine14.

Result and discussions

Sentinel-1 data consist of spackles which were removed using spackle filtering in SNAP. The spackle free image appeared comparatively bright and more appropriate to distinguish landuse features as shown in Figure 3.

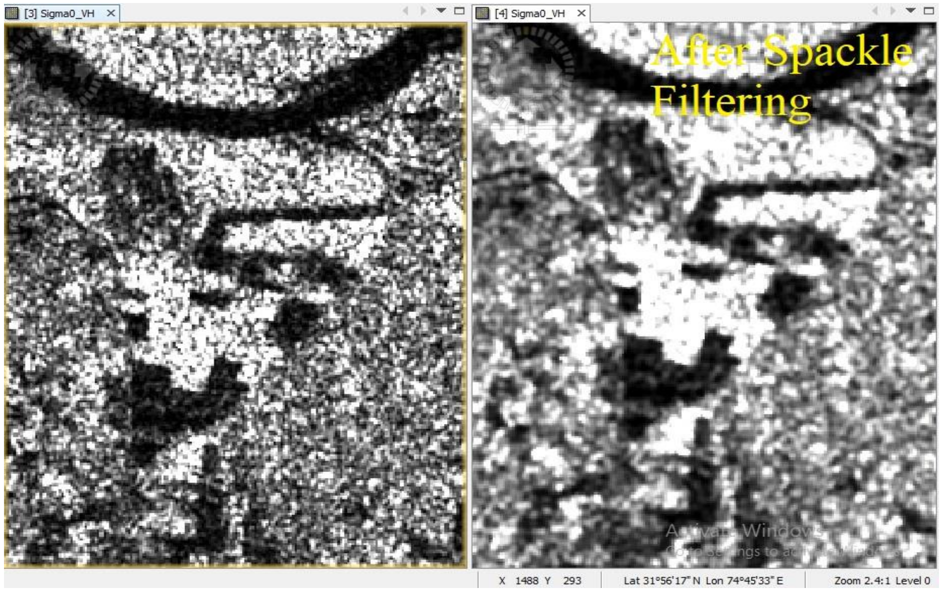

Figure 3. Spackle free image is appearing comparatively bright.

The Sentinel-1 image was made noise free by removing noise in thermal range and the noise free product is mapped in Figure 4 as below.

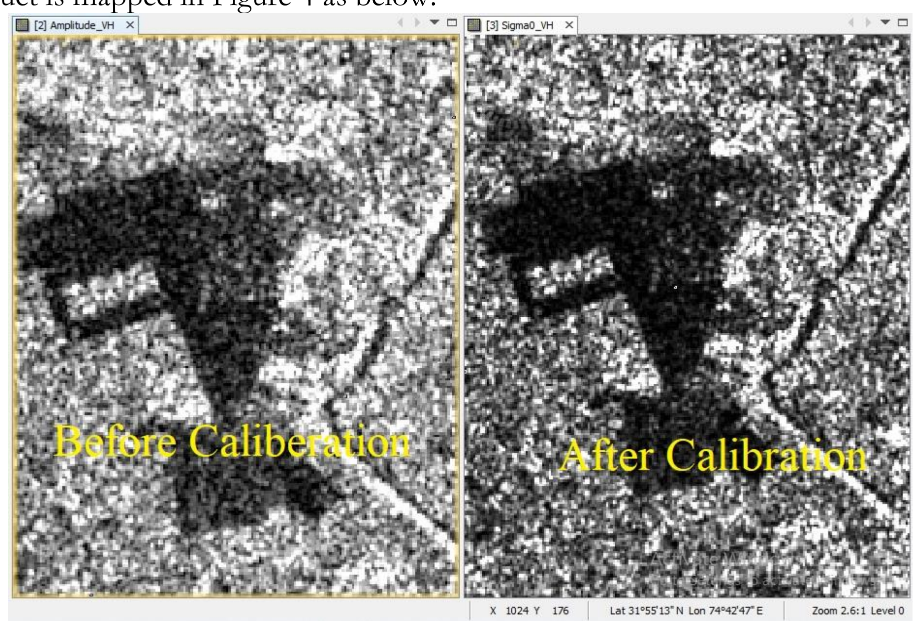

Figure 4. Thermal noise removal.

The resampling results are shown in Figure 5 where the pixel size was resampled to $10*10m^2$. The area under investigation was made subset by applying a mask using tools in SNAP and mapped the results in Figure 5.

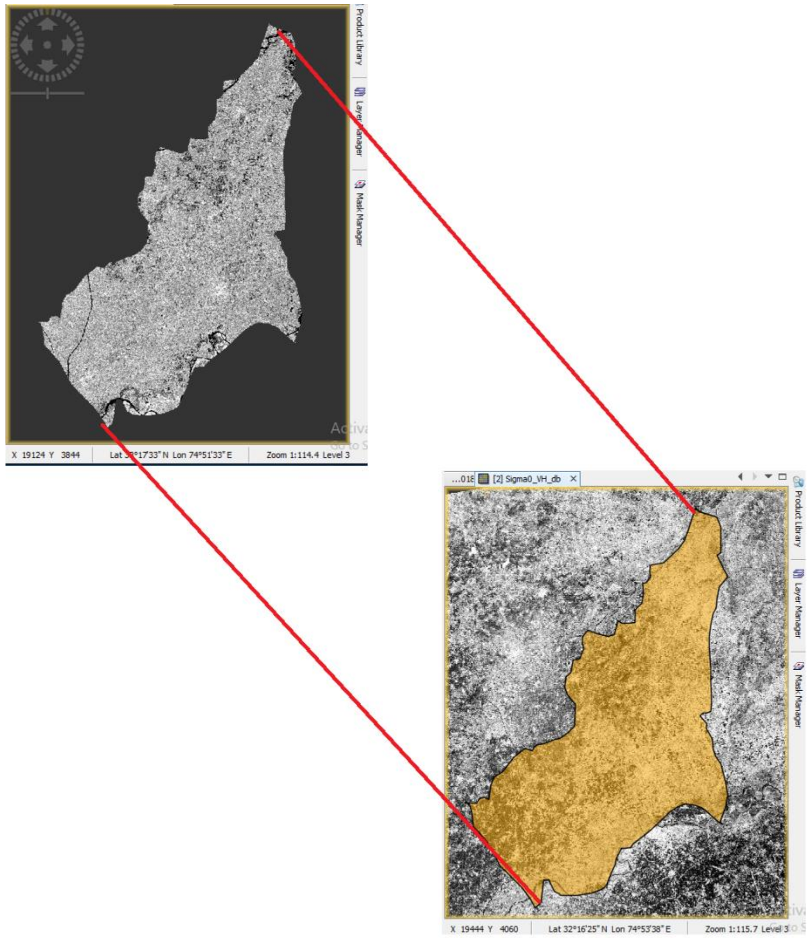

Figure 5. Subset of study site in SNAP.

We selected trainee vectors to differentiate between various landuse features including vegetation, built-up area and the water body and mapped the results in Figure 6.

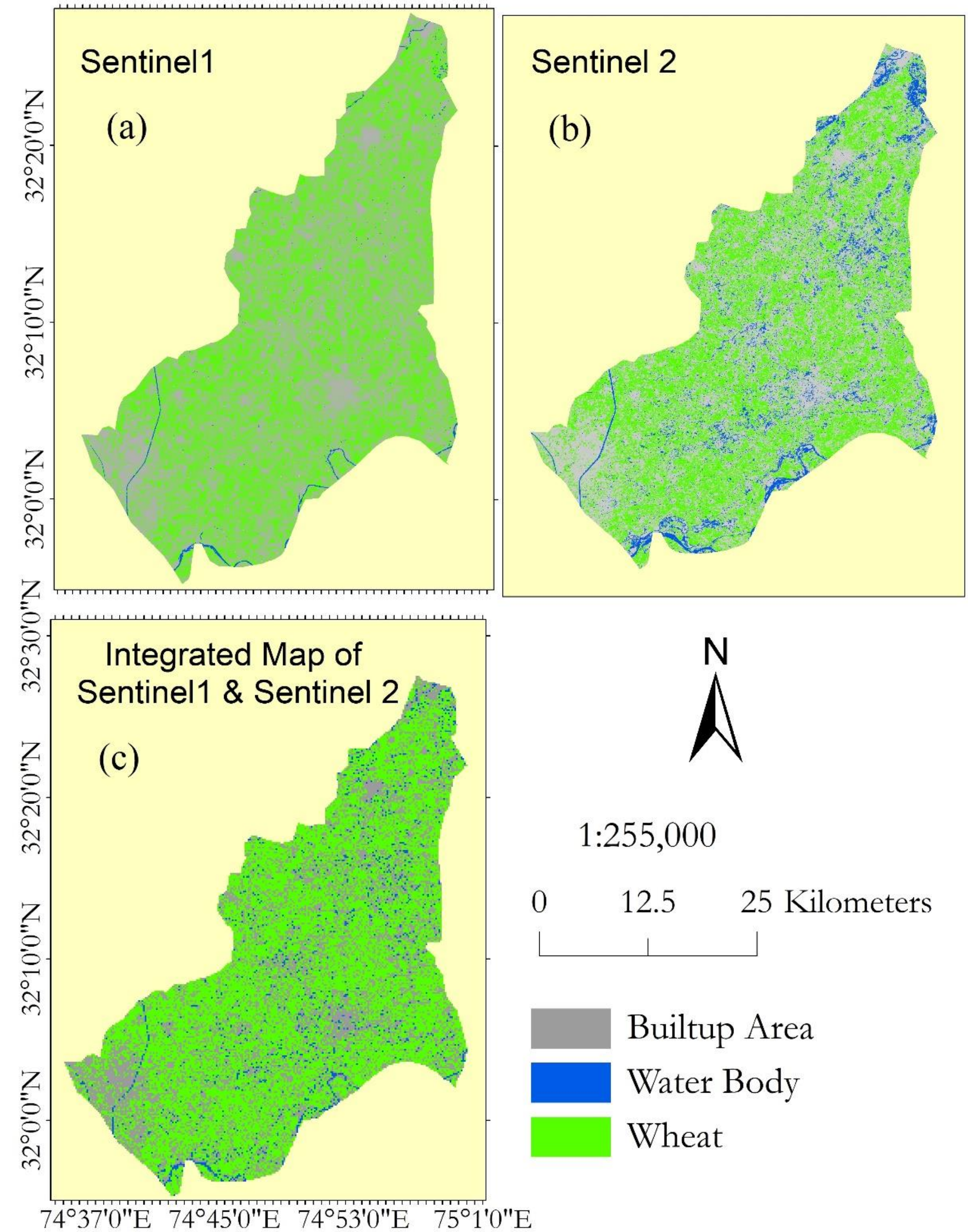

Figure 6. (a) Random forest classification by Sentinel-1 data (b) Supervised classification by Sentinel-2 data and (c) Integrated map of Sentinel-1 and Sentinel-2 data.

The supervised classification algorithm was applied to Sentinel-2 image in Erdas imagine 14 and mapped the results in Figure 6(b).

The random forest classification results of Sentinel-1 show that the total area under investigation was 1089km^2 which was further subdivided into three classes including wheat (551km^2), built-up (450 km^2) and the water body (89 km^2).

Supervised classification results of Figure 6(b) show that the area under wheat crop was 510 km^2, however the built-up and waterbody were 477 km^2, 102 km^2 respectively. To determine the accuracy of classification results, we applied Kappa stats to both classifications (RFC, Supervised).

We considered 25 sample points for built-up, water body and wheat crop to cross validate these points with their actual locations. The calculations of Sentinel-1 and Sentinel-2 data are as below,

Kappa Coefficient Sentinel-2 image.

TS= Total number of Sample

TSC= Total number of corrected Sample

$$\text{Kappa coefficients}(\mathcal{K}) = \frac{(\mathcal{TS} * \mathcal{TCS}) - \sum(col.total * Row\ total)}{(\mathcal{TS})^2 - \sum(col.total * Row\ total)} * 100$$

$$\mathcal{K} = \frac{[(25 * 21) - \{(15 * 15) + (5 * 5) + (5 * 5)\}]}{(25)^2 - \{(15 * 15) + (5 * 5) + (5 * 5)\}} * 100$$

$$\mathcal{K} = \frac{[(525) - \{(225) + (25) + (25)\}]}{(625) - \{(225) + (25) + (25)\}} * 100$$

$$\mathcal{K} = \frac{525 - 275}{625 - 275} * 100$$

$$\mathcal{K} = \frac{250}{350} * 100$$

$$\mathcal{K} = 0.714 * 100 = 71.42\%$$

Table 1 is showing that 21 samples out ot 25 could be cross matched properly and 2 samples of wheat are and 1,1 by buildup and water were found mismatched.

Table 1: Field survey data information about 2018

Class	**Wheat-Area**	**Build-up Area**	**Water**	**Total-User**
Wheat-Area	13	1	1	15
Build-up Area	1	4		5
Water	1		4	5
Total-Producer	15	5	5	25

Kappa Coefficient Sentinel-1 image.

TS= Total number of Sample

TSC= Total number of corrected Sample

$$\text{Kappa coefficients}(\mathcal{K}) = \frac{(\mathcal{TS} * \mathcal{TCS}) - \sum(col.total * Row\ total)}{(\mathcal{TS})^2 - \sum(col.total * Row\ total)} * 100$$

$$\mathcal{K} = \frac{[(25 * 22) - \{(15 * 15) + (5 * 5) + (5 * 5)\}]}{(25)^2 - \{(15 * 15) + (5 * 5) + (5 * 5)\}} * 100$$

$$\mathcal{K} = \frac{[(550) - \{(225) + (25) + (25)\}]}{(625) - \{(225) + (25) + (25)\}} * 100$$

$$\mathcal{K} = \frac{550 - 275}{625 - 275} * 100$$

$$\mathcal{K} = \frac{275}{350} * 100$$

$\mathcal{K} = 0.785 * 100 = 78.57\%$

Table 2 determine that 23 sample points out of total 25 samples could be cross matched but there was error while matching 1,1 sample for water and wheat respectively.

Table 2: Field survey data information about 2018

Class	Wheat-Area	Build-up Area	Water	Total-User
Wheat-Area	14		1	15
Build-up Area	1	4		5
Water		1	4	5
Total-Producer	15	5	5	25

The results show that the accuracy of supervised classification of Sentinel-2 data was 71% while Sentinel-1 data presented comparatively good results with an accuracy of 78%.

To enhance the accuracy of supervised classification, we averaged both classifications and mapped the results in Figure 6(c) which show that the area under wheat was 531 km^2 and the other features including water body and the built-up area were 95 km^2 and 463 km^2 respectively.

Kappa Coefficient on integrated map

TS= Total number of Sample

TSC= Total number of corrected Sample

$$\text{Kappa coefficients}(\mathcal{K}) = \frac{(\mathcal{TS} * \mathcal{TCS}) - \sum(col.total * Row\ total)}{(\mathcal{TS})^2 - \sum(col.total * Row\ total)} * 100$$

$$\mathcal{K} = \frac{[(25 * 23) - \{(15 * 16) + (5 * 5) + (5 * 4)\}]}{(25)^2 - \{(15 * 16) + (5 * 5) + (5 * 4)\}} * 100$$

$$\mathcal{K} = \frac{[(575) - \{(240) + (25) + (20)\}]}{(625) - \{(240) + (25) + (20)\}} * 100$$

$$\mathcal{K} = \frac{575 - 285}{625 - 285} * 100$$

$$\mathcal{K} = \frac{290}{340} * 100$$

$$\mathcal{K} = 0.85 * 100 = 85\%$$

Table 3 is showing that 23 samples out of 25 were matched.

Table 3: Field survey data information about 2018

Class	Wheat-Area	Build-up Area	Water	Total-User
Wheat-Area	15			15
Build-up Area	1	4		5
Water		1	4	5
Total-Producer	16	5	4	25

The kappa statistics of this integrated map was computed and the results showed the accuracy as 85% which was very near to ground reality.

Conclusions.

This study describes a comparative analysis of Sentinel-1 and Sentinel-2 datasets which presented a real picture of area under wheat cultivation. It was observed that Sentinel-1 data was better than Sentinel-2 data for estimation of crop area, however the integrated map of Sentinel-1 and Sentinel-2 data give more accurate classification results.

Author's Contribution. All the authors contributed equally.
Conflict of interest. We declare no conflict of interest to publish this research in IJASD.

References

1. Godfray H. C. J. et al. Food security: the challenge of feeding 9 billion people. Science 327, 812–818 (2010)
2. Tilman D., Balzer C., Hill J., Befort B. L. Global food demand and the sustainable intensification of agriculture. Proc. Natl Acad. Sci. USA 108, 20260–20264 (2011)
3. United Nations, Department of Economic and Social Affairs. Population division, population estimates and projections section. http://esa.un.org/unpd/wpp/index.htm
4. Foley J. A. et al. Solutions for a cultivated planet. Nature 478, 337–342 (2011)
5. Cassman K. G. Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture. Proc. Natl Acad. Sci. USA 96, 5952–5959 (1999)
6. Finger R. Evidence of slowing yield growth—the example of Swiss cereal yields. Food Policy 35, 175–182 (2010)
7. Peltonen-Sainio P., Jauhiainen L., Laurila I. P. Cereal yield trends in northern European conditions: changes in yield potential and its realization. Field Crop Res. 110, 85–90 (2009)
8. Hafner S. Trends in maize, rice, and wheat yields for 188 nations over the past 40 years: a prevalence of linear growth. Agricult. Ecosys. Environ. 97, 275–283 (2003)
9. Kendall H., Pimentel D. Constraints on the expansion of global food supply. Ambio 23, 198–205 (1994)
10. Brisson N. et al. Why are wheat yields stagnating in Europe? A comprehensive data analysis for France. Field Crop. Res. 119, 201–212 (2010)
11. Lin M., Huybers P. Reckoning wheat yield trends. Environ. Res. Lett. 7, 024016 (2012)
12. Ladha J. K. et al. How extensive are yield declines in long-term rice-wheat experiments in Asia? Field Crop Res. 81, 159–180 (2003)
13. Sacks J. et al. Monitoring the worlds agriculture. Nature 466, 558–560 (2010)
14. Food and Agriculture Organization of the United Nations (FAOSTAT). http://faostat.fao.org/site/567/default.aspx#ancor. Accessed on March 2011
15. Parsons D. et al. Managing maize production in shifting cultivation milpa systems in Yucatan, through weed control and manure application. Agricult Ecosys. Environ. 133, 123–134 (2009)
16. Deepak K. Ray, Navin Ramankutty, Nathaniel D. Mueller, Paul C. West & Jonathan A. Foley "Recent patterns of crop yield growth and stagnation" Nature 2012
17. Qadir M., Sharma B.R., Bruggeman A., Choukr-Allah R., Karajeh F. Non-conventional water resources and opportunities for water augmentation to achieve food security in water scarce countries. Agric. Water Manag. 2007;87:2–22.
18. Karamat.A, Nawaz.M, Mirza A.I, Jamil.M.R, Asghar.A, Ayyaz.M, Akram.F and Mahmood.S.A.". Step-by-Step Processing of Sentinel-1 data for Estimation of Rice Area. International Journal of Agriculture and Sustainable Development, Vol 01 Issue 02: pp 66-80, 2019.
19. Behzad.A; Rafique.U; Qamar.M; Islam.B, H Umer Hameed,U.H; Basheer M, Firdos.M and Mahmood.S.A1". Estimation of Net Primary Production of Rice Crop using CASA model in Nankana Sahib. International Journal of Agriculture and Sustainable Development, Vol 01 Issue 01: pp 30-46, 2019.

20. Saifullah M, Islam.B, Rehman.S, Shoaib M, Haq.E, Gillani.S.A, Farooq.N, Zafar.M". Estimation of Water Stress on Rice Crop Using Ecological Parameters. International Journal of Agriculture and Sustainable Development, Vol 01 Issue 01: pp 17-29, 2019.
21. Charles Peter MgeniZ, Sunflower Value Chain Enhancements for the Rural Economy in Tanzania: A Village Computable General Equilibrium-CGE Approach, Sustainability 2018.
22. Rebecca Lima Albuquerque Maranhão The Spatiotemporal Dynamics of Soybean and Cattle Production in Brazil Sustainability 2019.
23. Gurpreet Kaur ,Brendan Zurweller ,Peter P. Motavalli andKelly A. Nelson Screening Corn Hybrids for Soil Waterlogging Tolerance at an Early Growth Agriculture 2019, 9(2), 33; Stagehttps://doi.org/10.3390/agriculture9020033
24. Gumma, M. K., Thenkabail, P. S., Maunahan, A., Islam, S., & Nelson, A. (2014). Mapping seasonal rice cropland extent and area in the high cropping intensity environment of Bangladesh using MODIS 500m data for the year 2010. *ISPRS Journal of Photogrammetry and Remote Sensing*, *91*, 98–113. https://doi.org/10.1016/j.isprsjprs.2014.02.007.
25. Asilo, S., de Bie, K., Skidmore, A., Nelson, A., Barbieri, M., & Maunahan, A. (2014). Complementarity of t wo rice mapping approaches: Characterizing strata mapped by hypertemporal MODIS and rice padd y identification using multitemporal SAR. Remote Sensing, 6(12), 12789–12814. https://doi.org/10.339 0/rs61212789