50SEA.COM

IJASD
ISSN 2618-1193

Step-by-Step Processing of Sentinel-1 data for Estimation of Rice Area.

Awais Karamat[1], Muhammad Nawaz[1], Ali Imam Mirza[2], Muhammad Rahat Jamil[1], Ali Asghar[3], Muhammad Ayyaz[1], Fareeha Akram[4] and Syed Amer Mahmood[1].

[1]RS/GIS group Department of Space Science University of the Punjab Lahore Pakistan.
[2] Department of Geography, GCU Lahore, Pakistan.
[3] Institute of management and sciences (Pak AIMS)
[4] Soil fertility, research institute Punjab Pakistan.
* Correspondence: Awais Karamat E-mail : awaiskaramat89@gmail.com
Citation | 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.
DOI | https://doi.org/10.33411/IJASD/2019010204
Received | March 20, 2019; Revised |April 23, 2019 Accepted | April 25, 2019; Published | April 28, 2019.

Abstract.

Rice has become an essential part of four pillars of food security, especially in Asia, where it is produced over large spatial extents and also consumed widely. About 89 % of the global rice production is targeted and achieved from Asian countries. We downloaded Sentinel-1 datasets from official website of European Space Agency (ESA) for identification of rice patterns in the study site. The data was selected in Ground Range Detection (GRD) format and applied the toolbox in Sentinel Application Platform (SNAP) for further processing. We applied the orbit file for geometric and radiometric corrections, LEE filter for removal of spackles, resampling to convert 20*20m^2 to 10*10m^2 pixel size and finally the Random Forest Classification (RFC) to classify the satellite image. The classification results of Sentinel image for the year 2018, show that the total area of the study site was 360021 ha, including 144991 ha as rice area, 130598 as other vegetation, 19339 ha as water body and the built-up area was estimated as 5693 ha. Kappa statistics resulted the overall accuracy of 85% which is in strong agreement to ground reality. We observed that the rice area was increased from 140403 ha in 2017 to 144991 ha in 2018. The main reason of this increase in rice area was observed as the preference of local farmers to grow rice in comparison to other crops because the local government was offering high subsidy to rice farmers. Moreover, district

Nankana-Sahib produces rice of expert quality which is famous throughout the world therefore, it is considered as cash crop.

Keywords: Sentinel-1, Random Forest Classification, SNAP, GRD, LEE filter.

Introduction.

Rice has become an essential part of four pillars of food security, especially in Asia, where it is produced over large spatial extents and also consumed widely [1]. About 89 % of the global rice production is targeted and achieved from Asian countries [2,3] and this target is anyhow achieved. Climatology and soil suitability are considered important to examine the sustainable sites for rice cultivation [4,5]. Many countries have initiated the automated information system to record rice related information e.g., Philippine Rice Information System (PRIS) was implemented to monitor various types of insects of rice crop.

Geo Global Agriculture Monitoring (Geo GIAM) was setup to reduce diseases in rice crop by integration of field data with satellite images. Crop reporting system is concise comprehensive and efficient system which is comprised of crops, soil, weeds, insects and pathogens which transform nutrients, water and solar energy in to feed, food, fuel and fiber [6]. Rice is a main crop which can be grown two times in the same field in a year [7]. Rice cropping patterns are of great importance for researchers, policy makers, land managers and agricultural planners to monitor the growth index and to collect spatial information about these patterns [8].

The manual procedures to collect crop related information are time consuming laborious and expensive. The traditional methods of field data collection have very low temporal resolution, even one cannot get pixel-based information using these methods because many areas are inaccessible during field visits [9]. These methods get fail for providing timely updates with precision for large spatial extents. The availability of multispectral and hyper-spectral satellite imagery at high temporal resolution, provide pixel-based crop related information to map crop growth and development over vast landscapes [10].

Rice crop has three phases of growth which include vegetative phase, reproductive phase and finally the ripening phase. Vegetative phase is subdivided into germination, tillering and stem elongation. The weight of rice seed often remains between 12-44 mg which depends upon the variety of rice. First the seed dormancy is broken and the white tip appears from water/land called germination. It takes about 4-10 days as it depends upon the rice environmental conditions faced by the rice crop. The next phase starts from leaf emergence, that take about 8-12 days for the appearance of four leaves. It takes about 100-degree days for emergence of a leaf [11]. Therefore, a leaf is emerged on 4th day for a rice plant bearing 25^{o}C (100/25 = 4 days). Tillers are the branches, that emerges after emergence of 4th leaf on the main culm [12]. Next stages include initiation of panicle primordia, heading /anthesis, flowering, milky dough and hardening of grains [13].

The reproductive stage is completed within 35 days and the ripening stage takes about 30 days for completion [14]. At ripening stage, irrigation/watering is stopped in the rice fields, as penalty of water has already been provided in early stages. This scheme of provision of water is quite different for other crops like wheat, maize or sugarcane etc. The remote sensing satellites capture the crop canopy responses in form of solar energy reflected in visible and microwave ranges [15]. This determine that each crop has unique spectral signature which varies depending upon the canopy structure, chlorophyll level, and the available water content.

The main objective of this research was to estimate net rice area through microwave remote sensing using Sentinel-1 imagery. Sentinel-1 imagery is the product of European Space Agency (ESA) which is difficult to manipulate and need complex algorithms to obtain fruitful results [16].

Materials and Methods.

Study site.

This research was carried out in Nankana Sahib, Punjab province in Pakistan. The study site is famous for production of high quality of rice throughout the world. It is a plane area which is in range of monsoon season therefore, it receives excess of rainfall which is a good sign for proper growth of rice crop [17]. However, there exist a cemented network of water channels for provision of water to the rice crop. The spatial extent of the study site is mapped in Figure 1.

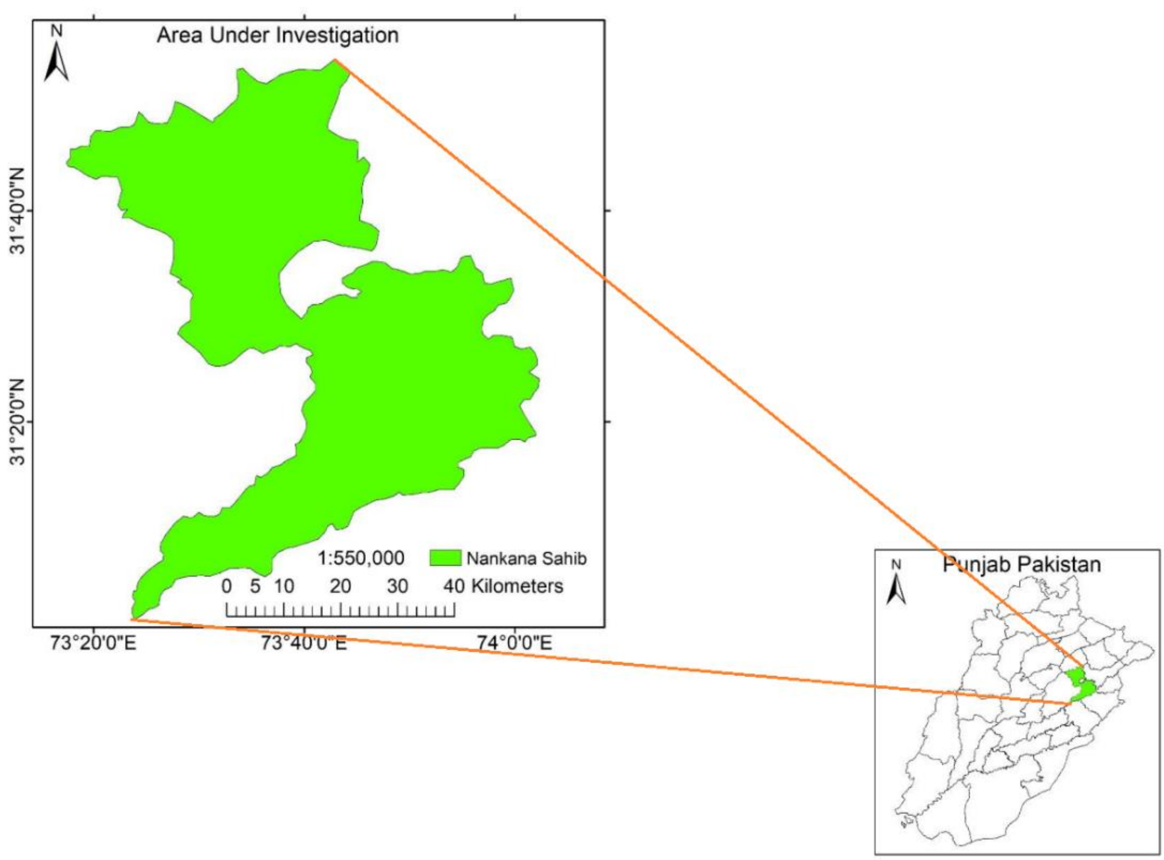

Figure 1. Study area.

Material.

Various crops planted over vast fields, are difficult to recognize in satellite image, however, unique spectral signatures are available which are specific for a crop [18]. Optical sensors provide passive datasets, which have been widely utilized to delineate cropping patterns on large spatial extents. Gumma et al., 2014 [19] used MODIS 8 days composites having coarse resolution of 500 m to map rice cropping patterns in Bangladesh. Asilo et al., 2014 [10], used MODIS NDVI datasets to map cropping patterns in Pangasiran and Ecija provinces.

Active remote sensing has become a need of the day because of its wider applications, e.g., Synthetic Aperture Radars (SAR) are capable to record temporal backscatter of various crops. The signal in microwave range which is reflected back toward the radar antenna is known as backscatter. Various crop types can be detected by radar signal on the basis of crop condition, crop type and the growth stage [20]. Rice is a paddy crop which require highly inundated fields and there is a different behavior of water for microwave signal in comparison to surrounding features, therefore, rice fields are discriminated easily by their backscatter profiles [21].

Sentinel-1 is upgraded version of European Space Agency (ESA) in term of large spatial coverage having high temporal resolution. Sential-1A was launched on April 03, 2014, having high spatial resolution of 20m with a temporal window of 12days. Sentinel-1-B was launched to reduce the revisit time of sentinel satellites [22]. Sentinel-1 C band has dual polarization which is capable to transmit and receive signals in both vertical and horizontal polarizations. Level-1 SAR data is available in vertical-vertical (VV) horizontal- horizontal (HH) and in dual polarizations (VV+VH and HH+HV).

Field data about rice fields was collected using Differential Global Positioning System (DGPS) to demarcate rice plots. The non-rice features e.g., trees, Jowar and bushes were subtracted to select the rice only.

Methodology.

The complete flow of study is described in Figure 2.

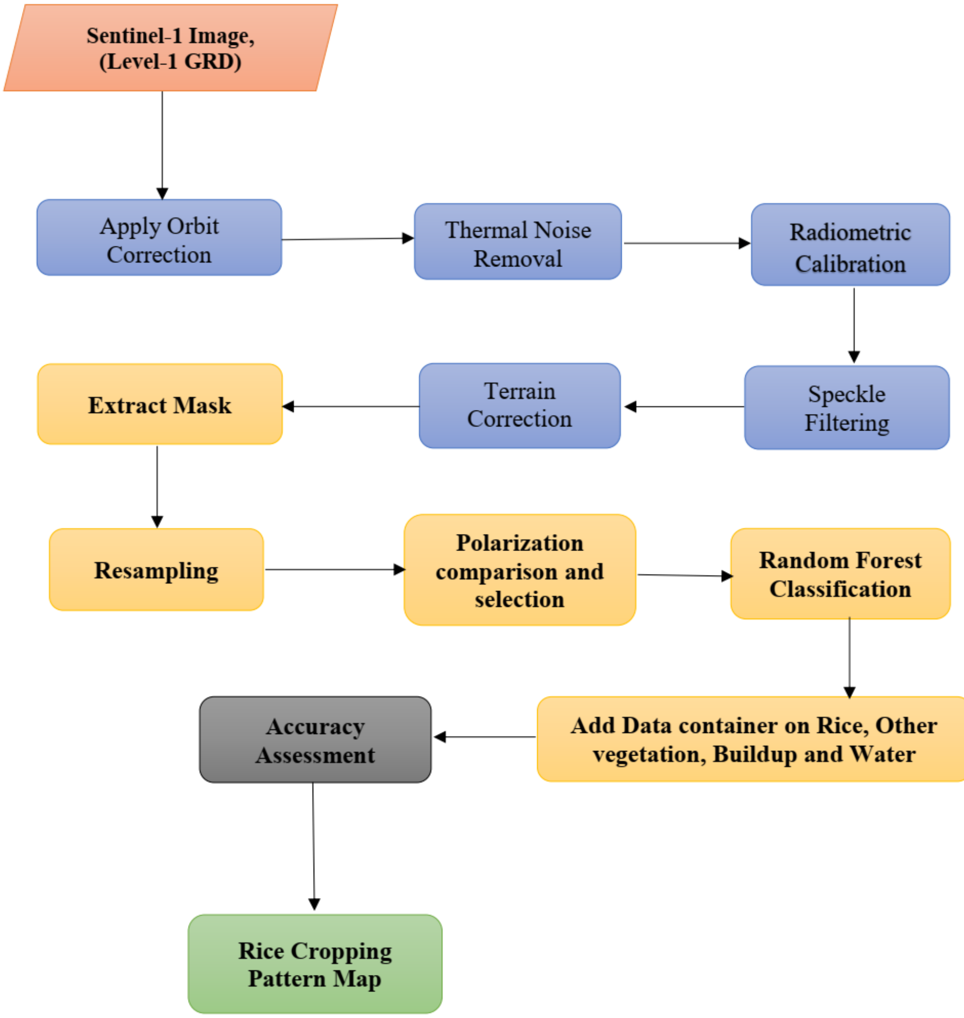

Figure 2. Flow of study.

Sentinel-1 Pre-Processing.

We downloaded SAR datasets from official website of ESA for identification of different rice patterns in the study site. This data was selected in Ground Range Detection (GRD) format and applied the toolbox in Sentinel Application Platform (SNAP) for further processing.

Application of orbit file.

In the first step of pre-processing, we applied an orbit file which is required to make geometric and radiometric corrections. The orbit file preserves the accurate information about position and velocity of the satellite. This is useful to update the orbit state vector in metadata of SAR images. The geometric corrections are essential to perform comparative study of SAR images acquired in different modes at different times by different sensors [23].

Spackle filtering.

There are salt and peppery structures in SAR images which are called spackles. spackles are created by constructive/destructive interference of microwave signals. Spackles reduces the image quality which must be removed. We applied a refined LEE filter to get spackles free SAR image. LEE filter suits best while incorporating the rice crop.

Thermal noise.

Thermal noise is created within SAR images due to microscopic movement of electrons created by variations in temperature. The circularity of satellite is also responsible for generation of thermal noise. We used the option of "SAR Thermal Noise Removal" in Radiometric tools of Radar in SNAP.

Terrain Correction.

The actual topographical variations cause a tilt or distortion in the backscatter. Therefore, terrain correction is an essential phase of preprocessing to compensate these distortions. We performed terrain correction in SNAP toolbox.

Resampling.

Resampling is an elegant technique which is used to convert a large pixel size image in to small sized boxes e.g., Sentinel-1 has a pixel size of 20*20 m^2 which was converted to 10*10m^2 to obtained more efficient classification results. Resampled image takes more processing time but return more accurate and improved classification results.

Sub-setting.

Sub-setting is essential to extract the area of interest from a large dataset which results in speedy processing within short duration. The swath width of a sentinel Image is 400Km^2 which need penalty of time for data processing, however sub-setting results efficient in short duration. We used a shapefile of the study site to figure out the exact area of interest.

Selection of Trainee patterns.

Sentinel data has basically two types of polarization, vertical-vertical (VV), vertical horizontal (VH). These polarizations are effective to discriminate the rice crop in comparison to other vegetation. We applied VV and VH polarizations to demarcate the rice crop and selected trainee patterns. These trainee patterns are considered as seeds to apply Random Forest Classification (RFC). RFC is an algorithm of supervised classification embedded in SNAP toolbox which consider trainee vectors as input to classify the targeted Sentinel-1 data.

Result and Discussions.

The spackles were removed from the Sentinel-1 data as shown in Figure 3. This figure is showing that the study area bounded in blue box is dull and fuzzy in comparison to the area marked within yellow polygon which is showing bright patches with discrete boundaries. Actually, the area bounded in yellow polygon was spackle free.

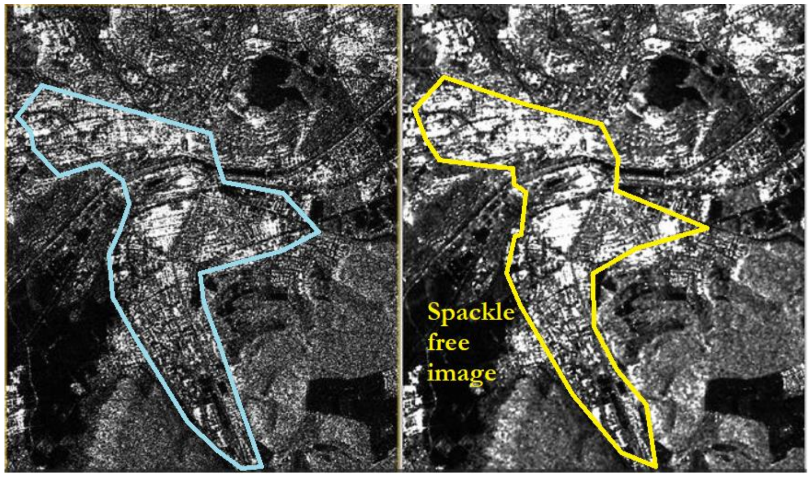

Figure 3. Acquisition of spackle free image by applying LEE filter.

We removed thermal noise from the Sentinel-1 data and mapped the results in the Figure 4. Two lines are marked in the upper side image within yellow circles which are not in the lower side image where is free of thermal noise.

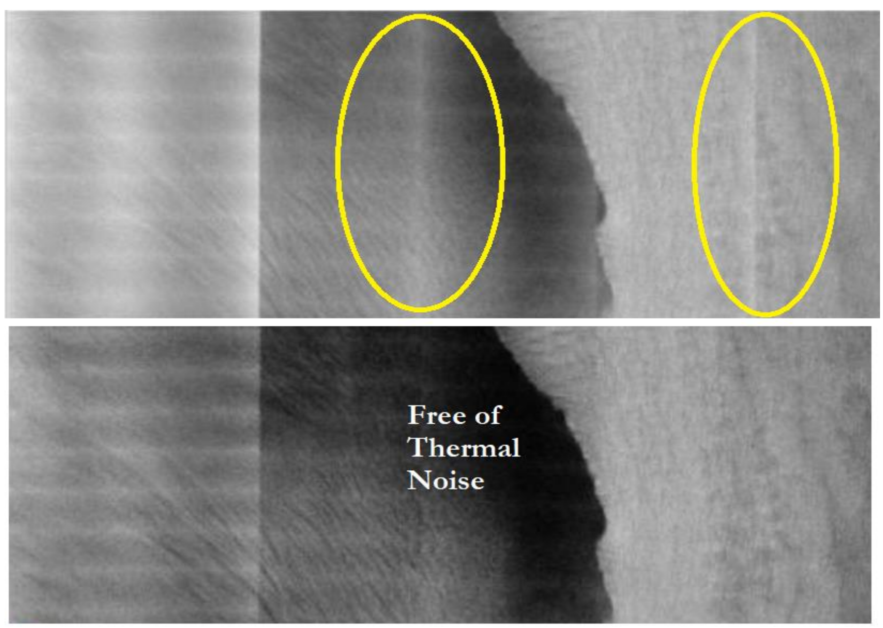

Figure 4. A comparison of noisy image with noise free image.

Resampling of Sentinel-1 data was performed using SNAP toolbox and cell size was reduced to $10*10m^2$ pixel size in comparison to the actual $20*20m^2$ as shown in Figure 5. It was a time-consuming process however it improved the RFC results.

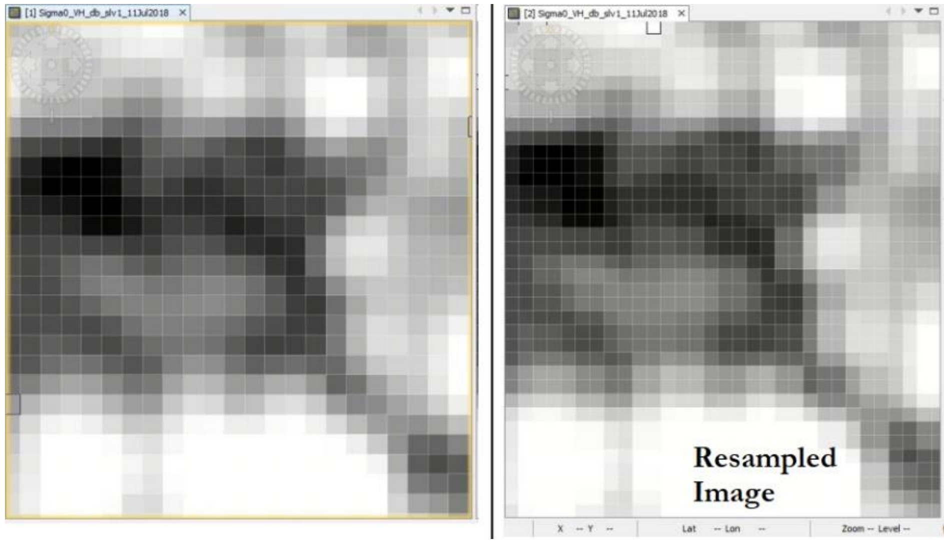

Figure 5. Conversion of $20*20m^2$ pixel to $10*10m^2$.

We obtained the actual extent of "Area of Interest" for RFC by applying a mask of the study site in SNAP platform and mapped the results in Figure 6.

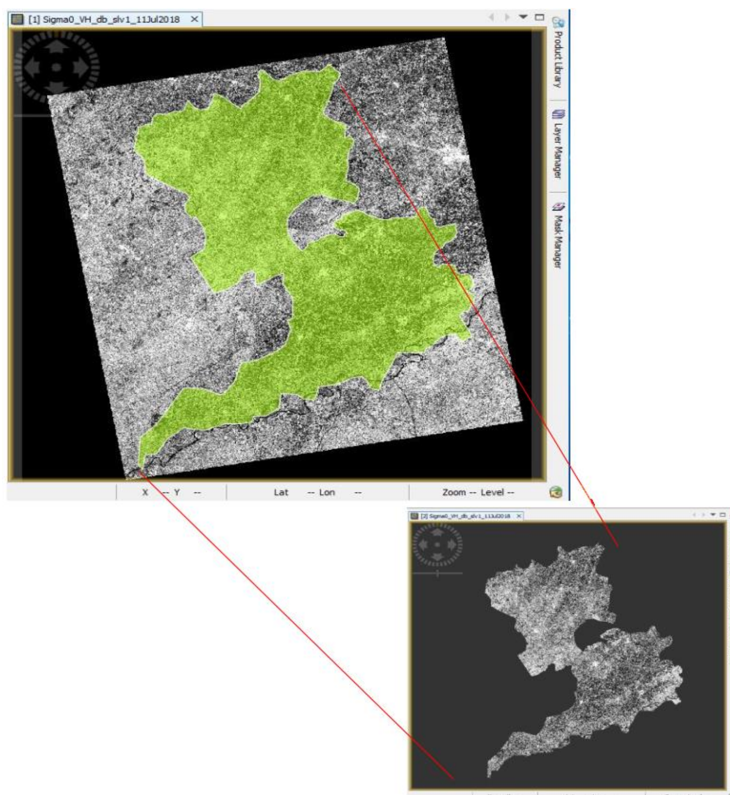

Figure 6. Subsetting of the study site.

Input training vectors were drawn on Sentinel image to recognize the human settlements, water body, vegetation and the rice fields. The landuse of the study site was classified using RFC and mapped the results in Figure 7, which determine that the total area of the study site was 360021 ha, including 144991 ha as rice area, 130598 as other vegetation, 19339 ha as water body and the built-up area was estimated as 5693 ha.

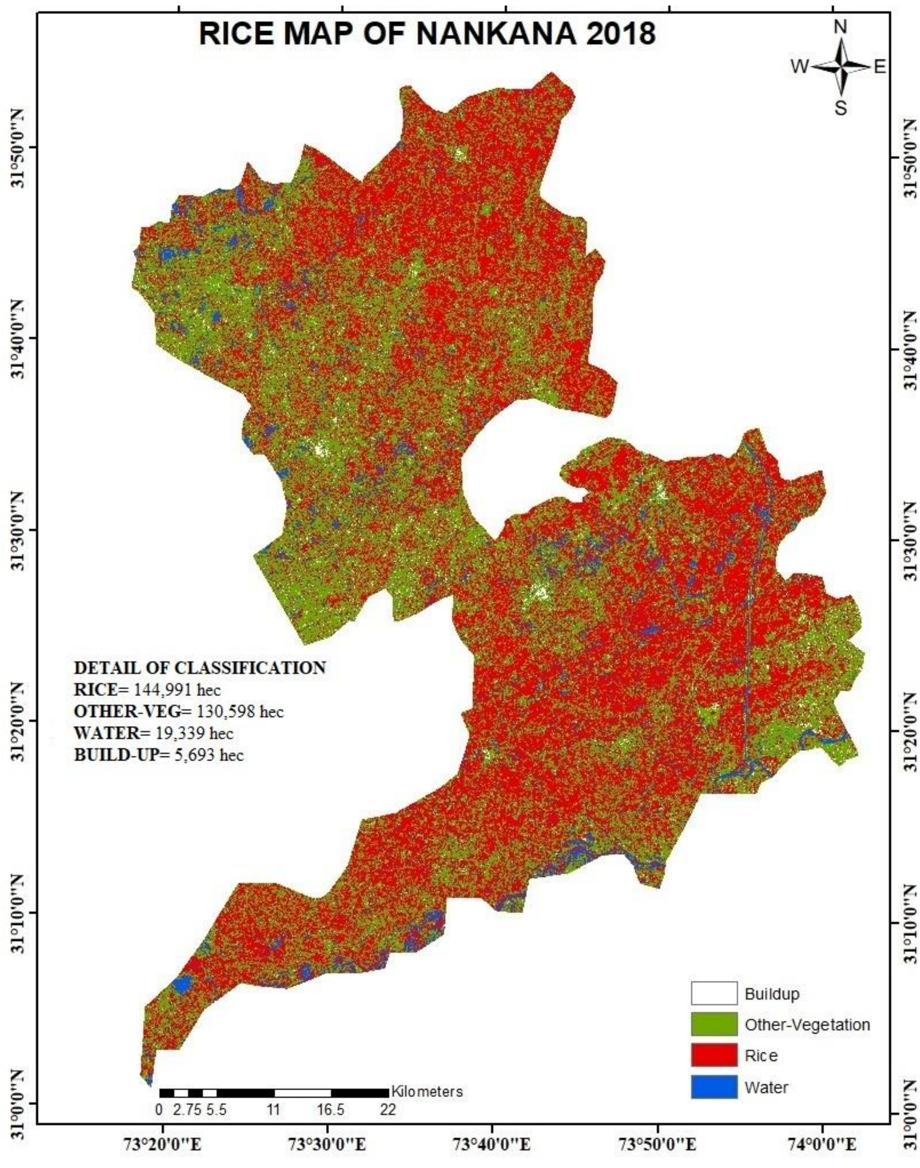

Figure 7. Classified map of Nankana Sahib for the year 2018.

To compute overall accuracy, we applied Kappa statistics to the study site. We marked 40 spatial locations in the study site which included 20 locations to demarcate the rice crop, 10 points for overall vegetation and 5 locations for water body and 5 for built-up area. The spatial locations of these 40 points were cross matched with their actual locations on the earth. Some remote locations were recognized through field survey which were not easy to identify on map/google earth. Overall accuracy was estimated as 85% as follows,

Kappa Coefficient 2018

TS= Total number of Sample

TSC= Total number of corrected Sample

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

$$\mathcal{K} = \frac{[(40 * 36) - \{(20 * 19) + (10 * 11) + (5 * 5) + (5 * 5)\}]}{(40)^2 - \{(20 * 19) + (10 * 11) + (5 * 5) + (5 * 5)\}} * 100$$

$$\mathcal{K} = \frac{[(1440) - \{(380) + (110) + (25) + (25)\}]}{(1600) - \{(380) + (110) + (25) + (25)\}} * 100$$

$$\mathcal{K} = \frac{1440 - 540}{1600 - 540} * 100$$

$$\mathcal{K} = \frac{900}{1060} * 100$$

$$\mathcal{K} = 0.849 * 100 = 85\%$$

According to Kappa standards, if the accuracy is greater than 80%, it is considered in strong agreement to ground reality. If the value of K lies between 40% and 80%, it represents middle accuracy and if K is less than 40%, it determines poor accuracy. Therefore, our results were in strong agreement.

We adopted the RFC to Sentinel-1 image acquired for the year 2017, to determine rice cropping patterns and mapped the classification results in Figure 8,

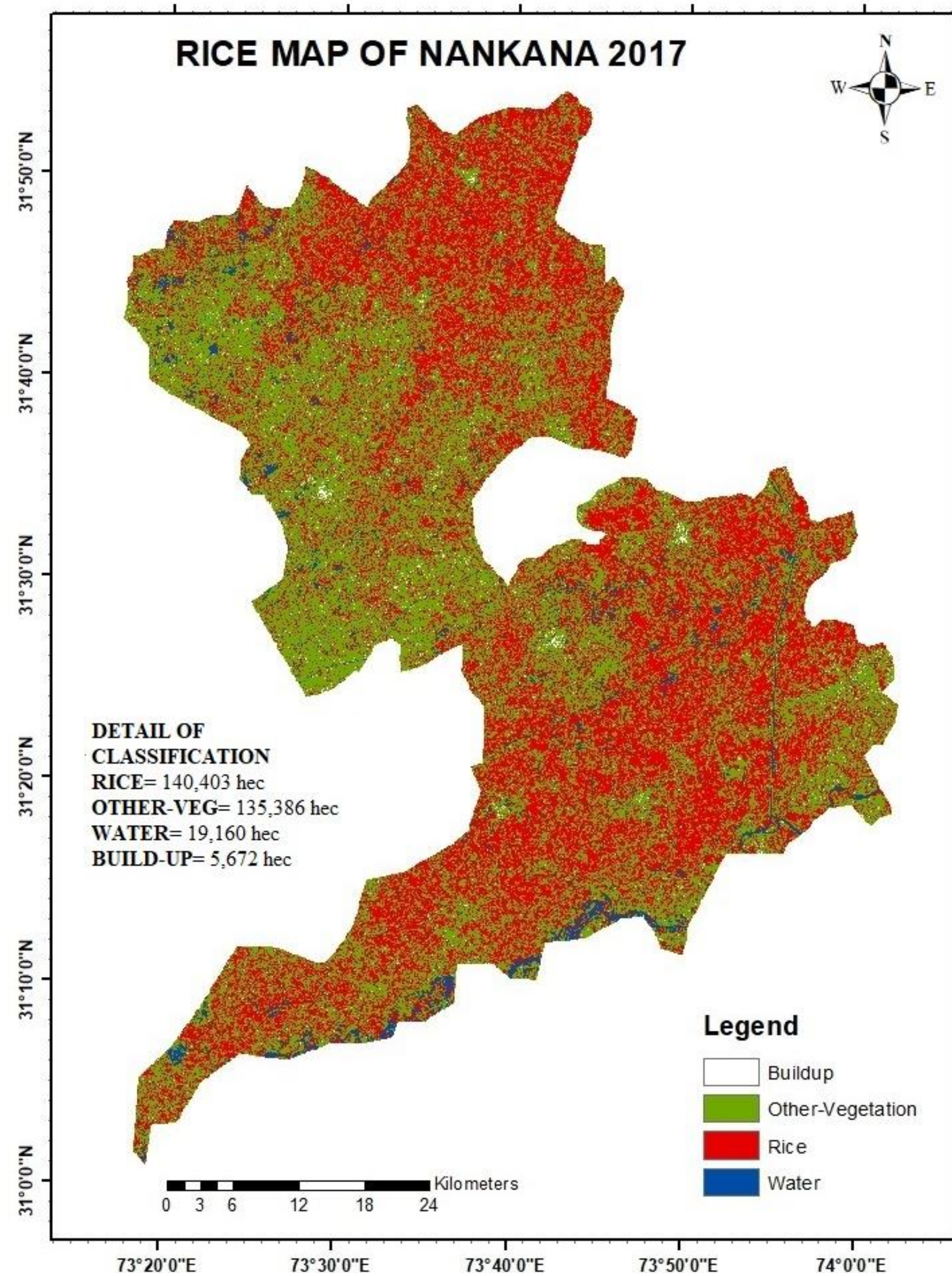

Figure 8. Classified map of Nankana Sahib for the year 2017.

The results show that the total area under investigation was 360021 ha, including 140403 ha as rice area, 135386 as other vegetation, 19160 ha as water body and the built-up area was estimated as 5672 ha.

For accuracy assessment of classification results, we applied Kappa statistics to the classified map. We marked 40 points on the classified map at various spatial location e.g., 20 for rice crop, 10 for vegetation and 5 for water body and 5 for built-up areas. The Kappa coefficient was computed as 81% which is also in strong agreement. The calculation of Kappa coefficient is as below.

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

$$\mathcal{K} = \frac{[(40 * 35) - \{(20 * 19) + (10 * 12) + (5 * 4) + (5 * 5)\}]}{(40)^2 - \{(20 * 19) + (10 * 12) + (5 * 4) + (5 * 5)\}} * 100$$

$$\mathcal{K} = \frac{[(1400) - \{(380) + (120) + (20) + (25)\}]}{(1600) - \{(380) + (120) + (20) + (25)\}} * 100$$

$$\mathcal{K} = \frac{1400 - 545}{1600 - 545} * 100$$

$$\mathcal{K} = \frac{855}{1050} * 100$$

$$\mathcal{K} = 0.81 * 100 = \quad 81\%$$

We observed that the rice area was increased from 140403 ha in 2017 to 144991 ha in 2018. The main reason of this increase in rice area was observed as the preference of local farmers to grow rice in comparison to other crops because the local government was offering high subsidy to rice farmers. Moreover, district Nankana-Sahib produces rice of expert quality which is famous throughout the world therefore, it is considered as cash crop.

Conclusions

This study is an amalgam of satellite data, field data and the farmer's opinions, which presents an elegant picture of rice cultivations in Nankana Sahib. We made an effort to define parameters for discrimination of rice in comparison to other crops. We used Sentinel-1 data in this research which is obtained in microwave range of electromagnetic spectrum that record the field observations in all types of weather conditions e.g., cloudy rainy and others. VV and VH polarizations are important to discriminate the rice crop from other vegetation, however multi-polarized data is recommended in future to obtain more appropriate results.

Acknowledgement. All praise is to ALLAH Almighty. I convey my modest gratitude to Him for the courage, determination, intellect and innumerable blessing upon me to complete my work. Special thanks to my Supervisor Dr. S M Hassan Raza, and my brother Sheeraz Karamat for his support, encourage, valuable comments and remarks to improve my work.

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. Pandey, S., Byerlee, D., & Dawe, D. (2010). Rice in the Global Economy: Strategic Research and Policy Issues for Food Security. … and Policy Issues …. International Rice Research Institute. Retrieved from http://irri.org /resources/publications/books/rice-in-the-global-economy-strategic-research-and-policy-issues-forfood-security

2. Karamat.A, Rehman.A, Ayyaz.M, Ali.S, Manzoor.I, Ashraf.A.H, Riaz.F, Tanveer.M.U and Mahmood.S.A". Estimation of Net Rice Production for the Fiscal year 2019 using Multisource Datasets. International Journal of Agriculture and Sustainable Development, Vol 01 Issue 02: pp 47-65, 2019

3. Yang, C.M.; Liu, C.C.; Wang, Y.W. Using FORMOSAT-2 satellite data to estimate leaf area index of rice crop. J. Photogram. Remote Sens. 2008, 13, 253–260

4. Cuerdo, G., Villano, L., Gutierrez, M. A., Garcia, C., Laborte, A., Boschetti, M., & Nelson, A. (2013). The when and where of rice. Rice Today, 12(2), 32–33. Retrieved from https://www.scribd.com/documen t/135034694/RT-Vol-12-No-2-the-When-and-Where-of-Rice#fullscreen=1

5. Hijmans, R. (2007). The where and how of rice. Rice Today, 6(3), 19–21. Retrieved from https://www.scrib d.com/document/34620921/Rice-Today-Vol-6-No-3

6. FAO. (1996). Agro-Ecological Zoning Guidelines. FAO Soils Bulletin 76, 3–5. Retrieved from https://ww w.mpl.ird.fr/crea/taller-colombia/FAO/AGLL/pdfdocs/aeze.pdf

7. FAO. (2005). Crops and cropping systems. In Conservation Agriculture: A manual for farmers and extension worke rs in Africa. (pp. 104–115). International Institute of Rural Reconstruction, Nairobi; African Conserva tion Tillage Network, Harare. Retrieved from http://www.fao.org/ag/ca/africatrainingmanualcd/pd f files/06crop1.pdf

8. Soo Chin Liew, Suan-Pheng Kam, To-Phuc Tuong, Ping Chen, Vo Quang Minh, & Hock Lim. (1998). Ap plication of multitemporal ERS-2 synthetic aperture radar in delineating rice cropping systems in the Mekong River Delta, Vietnam. IEEE Transactions on Geoscience and Remote Sensing, 36(5), 1412–1420. ht tps://doi.org/10.1109/36.718845

9. Mansaray, L. R., Zhang, D., Zhou, Z., & Huang, J. (2017). Evaluating the potential of temporal Sentinel-1 A data for paddy rice discrimination at local scales. Remote Sensing Letters, 8(10), 967–976. https://doi. org/10.1080/2150704X.2017.1331472.

10. 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

11. Raza, S.M.H., Mahmood, S.A., Khan, A.A. Delineation of Potential Sites for Rice Cultivation Through Multi-Criteria Evaluation (MCE) Using Remote Sensing and GIS Int. J. Plant Prod. (2018) 12: 1. https://doi.org/10.1007/s42106-017-0001-z

12. Le Toan, T., Ribbes, F., Li-Fang Wang, Floury, N., Kung-Hau Ding, Jin Au Kong, … Kurosu, T. (1997). Rice crop mapping and monitoring using ERS-1 data based on experiment and modeling results. IE EE Transactions on Geoscience and Remote Sensing, 35(1), 41–56. https://doi.org/10.1109/36.551933

13. Nelson, A., Setiyono, T., Rala, A. B., Quicho, E. D., Raviz, J. V., Abonete, P. J., … Ninh, N. H. (2014). To wards an operational SAR-based rice monitoring system in Asia: Examples from 13 demonstration si tes across Asia in the RIICE project. Remote Sensing, 6(11), 10773–10812. https://doi.org/10.3390/rs 61110773

14. Raza, S.M.H., S.A. Mahmood, V. Liesenberg, S.S. Hassan. 2018. Delineation of vulnerable zones for YSB attacks under variable temperatures using remote sensing and GIS. Sarhad Journal of Agriculture, 34(3): 589-598.

15. 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.

16. Nabi.G, Adeel. M, Alvi. S, Atiq. M.Z, Ahmad. A, Riaz. A, Raza. S, "Evaluation of LNG consumption in local market through GIS". International Journal of Innovations in Science and Technology, Vol 01 Issue 02: pp 79-88.

17. 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.

18. Nguyen, D. B., Clauss, K., Cao, S., Naeimi, V., Kuenzer, C., & Wagner, W. (2015). Mapping Rice Seasonal ity in the Mekong Delta with multi-year envisat ASAR WSM Data. Remote Sensing, 7(12), 15868–1589 3. https://doi.org/10.3390/rs71215808

19. 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

20. McNairn, H., Champagne, C., Shang, J., Holmstrom, D., & Reichert, G. (2009). Integration of optical and Synthetic Aperture Radar (SAR) imagery for delivering operational annual crop inventories. ISPRS Jo urnal of Photogrammetry and Remote Sensing, 64(5), 434–449. https://doi.org/10.1016/j.isprsjprs.2008.07. 006

21. Oyoshi, K., Tomiyama, N., Okumura, T., Sobue, S., & Sato, J. (2016). Mapping rice-planted areas using ti me-series synthetic aperture radar data for the Asia-RiCE activity. Paddy and Water Environment, 14(4), 463–472. https://doi.org/10.1007/s10333-015-0515-x

22. Potin, P., Bargellini, P., Laur, H., Rosich, B., & Schmuck, S. (2012). Sentinel-1 mission operations concept. In 2014 IEEE International Geoscience and Remote Sensing Symposium (pp. 1745–1748). Quebec City, QC, Canada: IEEE. https://doi.org/10.1109/IGARSS.2012.6351183

23. Lemp, D., & Koch, B. (2009). Forest monitoring using TerraSAR-X data—evaluation of processing meth ods and first results. Proceedings of TerraSAR-X Science Meeting, (March 2014). Retrieved from https:// www.researchgate.net/publication/260920517