Madras Agric. J., 2019; doi:10.29321/MAJ 2019.000325

RESEARCH ARTICLE

Mapping mango area using multi-temporal feature extraction from Sentinel 1A SAR data in Dharmapuri, Krishnagiri and Salem districts of Tamil Nadu

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Received : 14th October, 2019
Revised : 11th November, 2019
Accepted : 16th November, 2019

ABSTRACT

Judicious and reliable information on crop area and production for tactical and strategic decision making is the need of the hour by all stakeholders in agriculture, such as producers, processors, resource managers, marketing, finance, and the government. The lacunae in conventional methods of crop delineation and area estimation can be overcome by the scientific method of estimation using remote sensing and GIS techniques. Sentinel 1A SAR data pertaining to the 2018 year acquired at 12 days intervals were downloaded and processed for intensity in Mapscape software. Sentinel 1A is anactive SAR microwave data, which can capture crop characteristics irrespective of weather and illumination condition. Ground truth observations collected during a survey for mango / non-mango was used to derive mango signature from the processed satellite images. The dB values extracted as signature were then subjected to the Multi-Temporal feature extraction method to delineate the mango growing areas. Around 8015 ha and 31118 ha was mapped as mango growing areas in Dharmapuri and Krishnagiri districts, respectively. Accuracy assessment using the confusion matrix techniquewas done with the 40 per cent of the ground truth datedataand a kappa coefficient value of 0.71 was obtained which showed a good accuracy of estimation.

Keywords:*Mango area mapping, SAR data, Multi-Temporal feature extraction, Accuracy assessment.*

The Agricultural Policy program currently depends on the timely gathering of information with field and aerial surveys, which are operational systems that provide accurate data. However, it has a number of inherent drawbacks which includes difficulties in comparing statistics and validating field information collected by the various agencies. As they use different methodologies for monitoring and measuring their agricultural production and which are Time-consuming and expensive nature of frequent field trips and surveys.With the latest advances in remote sensing, it is now possible to provide precise information on crop acreage, crop health, yields, damages and losses during disasters. There is scanty or non availability of real-time spatial database on the area under plantation crops, which affect the market-oriented decisions by policymakers. Further, there is a large scope for area expansion and marketability of plantation crops and the possibility of establishing processing industries. Apart from these, effective technology transfer for increasing productivity and reducing post-harvest losses is also possible. SAR data have a proven ability to detect crops through the unique temporal signature of the backscatter coefficient (also termed sigma naught or σ°) exhibited by the crop. The use of SAR backscattering values in Rice, Groundnut, Maize and Banana were demonstrated successfully in identifying and discriminating the crops by Suga and Konishi, 2008, Bouvet et al., 2009, Pazhanivelanet al.¸2015, Mugilanet al., 2017 and Venkatesanet al., 2019.

It is clear from the literature that well-understood relationships exist between crop characteristics and backscatter coefficients from different wavelengths, and these relationships have been used to derive different types of algorithms for estimating crop characteristics from SAR data. For this reason, a rule-based classification approach is tested for crop area mapping that is based on a small number of rules and parameters that can be quickly fine-tuned from site to site and season to season. Conceptually, the classification approach is based on rules that are agronomically meaningful and, thus, easily understood and fine-tuned based on the local knowledge of the crop growing environment. The main objective of this study is to map the mango cultivated areas in three districts of Tamil Nadu using SAR datasets.

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MATERIAL AND METHODS

Study area: In Tamil Nadu state, Krishnagiri, Dharmapuri, Salem, Dindigul, Vellore, and Tiruvallur are the major mango growing districts, of which Krishnagiri, Dharmapuri and Salem districts contribute to more than 60 per cent in area and production. Strategically these three districts are located in the northern part of the Tamil Nadu adjoining plateau region which favours mango cultivation. Hence these three districts have been selected for conducting the research on mango area estimation. The total and cultivable mango area of the study area were collected from DES data (Table. 1)

Satellite data:Sentinel 1A imageries acquired at 12 days interval for the year 2018 was downloaded and subjected to series of pre-processing viz., strip mosaicking to combine individual scenes of a particular date, co-registration of SAR data for different dates, speckle filtering, terrain geocoding, radiometric calibration and normalization, ANLD filtering and development of intensity layers using customized Mapscape software. The pre-processed data was then subjected to the generation of BSQ (σ°) for further analysis. Holeczet al. (2013) designed a fully automated processing chain, which was used to convert the multi-temporal SAR data into terrain geo-coded σ° values. The processing chain is available as a module within the MAPscape software.

Ground truth collection:A stratified sampling method of survey was conducted in the study area to collect ground truth points for mango and non-mango areas. A total of 152 and 143 points consisting of both mango orchards and non-mango areas were collected from Krishnagiri and Dharmapuri districts during the 2018 season respectively. The ground truth information includes latitude and longitude of the place, age of orchard, planter information and details on the nearby mango processing industries.

Multi-Temporal feature extraction: A module named multi-temporal feature extraction of Mapscape software was used to discriminate against the mango area from other plantations. 60 per cent of the mango ground truth points collected from each district was used as a training site for developing mango signature from the BSQ generated from the pre-processed Sentinel 1A SAR data. The db values extracted from the signature were given as input in the multi-Temporal feature extraction module for delineating the mango area. The sequential methodology of delineating mango growing areas of the study districts from acquired satellite data is given in Figure 1.

Accuracy assessment: A standard confusion matrix was applied to the mango/non- mango validation points collected from ground truth with the area mapping, and the overall accuracy with kappa value were generated. The class allocation of each pixel in the classified image was compared with the corresponding class allocation on reference data to determine the classification accuracy. Forty per cent of the total ground reference data were used for validation. The pixels of agreement and disagreement are compiled in the form of an error matrix, where the rows and columns represent the number of all classes and the elements of matrix represent the number of pixels in the testing dataset (Lillesandet al., 2007). The overall accuracy, which is the percentages of correctly classified pixels lying along the diagonal, was determined as follows:

The kappa coefficient was estimated from the formula(Richards, 1993)

For an error matrix with r rows, and hence the same number of columns,

Where, A = the sum of r diagonal elements, which is the numerator in the computation of overall accuracy

B = sum of the r products (row total x column total)

N = the number of pixels in the error matrix (the sum of all r individual cell values)

RESULTS AND DISCUSSION

With the innovations in remote sensing technique through microwave SAR (Synthetic Aperture Radar) data and the automated chain processing in crop identification and mapping, has become feasible. Freely available Sentinel 1A SAR data acquired at 12 days interval fromJanuary 2018 to December 2018 was used for the investigation in assessing mango crop identification and area estimation in the study area of Krishnagiri, Dharmapuri and Salem districts of Tamil Nadu.

Table 1.Percent deviation of estimated mango area from DES data

Districts	Estimated Area (Ha)	DES Reported Area (Ha)	Deviation (%)
Krishnagiri	31118	36009	-13.58
Dharmapuri	8015	7948	0.84
Salem	4852	4871	-0.39

Area estimation: The backscattering co-efficient and multi-temporal features from the SAR sensor were extracted and used for mango area mapping. To facilitate training and validation of Mango crop identification and area mapping, the study area was surveyed and ground truth points for mango (235 points) and non-mango (60 points) crops were collected. These survey points were overlaid (60 percent of points) on the processed Sentinel 1A satellite data for Mango crop signature extraction. The processed satellite files were then subjected to multi-feature extraction using the extracted mango signatures for obtaining area maps. The backscattering co-efficient and multi-temporal features as influenced by the crop growth parameters of Mango and underlying soil surface were extracted.

Table 2.Confusion Matrix for accuracy assessment in the study districts

Obtained Actual class from survey	Predicted class from the map			
	Class	Mango	Non- Mango	Accuracy
	Mango	80	13	86.0%
	Non-Mango	4	20	83.3%
	Reliability	95.2%	60.6%	85.5%
Average accuracy				84.7%
Average reliability				77.7%
Overall accuracy				85.5%
Kappa index				0.71

Temporal backscatter values were extracted for the ground truth points selected randomly over the study area. In Salem and Krishnagiri districts, backscattering values were found to be ranging from -10.99 to -9.56 dB and -10.77 to -8.92 dB in VV polarization at early stages. The backscattering

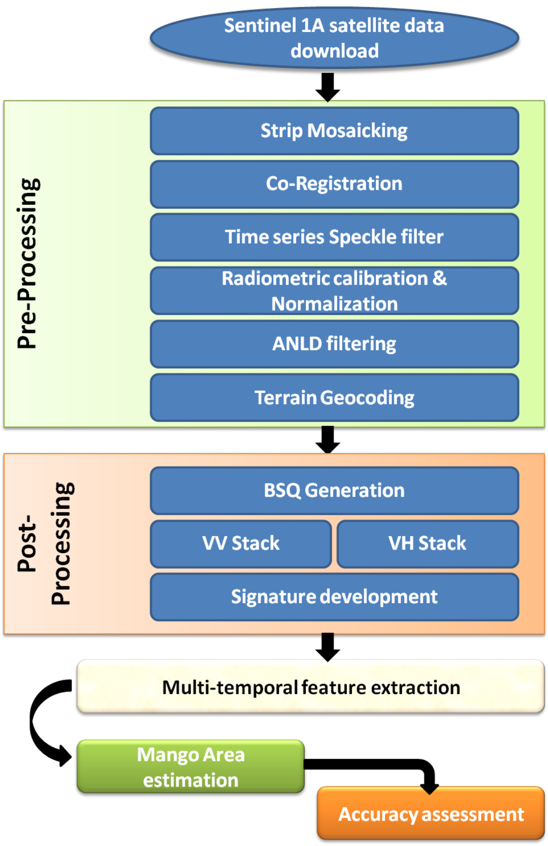

Figure 1. Flowchart indicating the methodology adopted for Mango mapping

values increased further and reached a maximum of -8.12 to -5.62 dB during the later stages of the year. In the case of VH polarization in these districts, the dB values were minimum at the early stage ranging from -18.57 to -17.79 and maximum at later stages with dB values ranging from -15.71 to -14.15. The maximum, minimum and mean temporal backscattering values for Vertical-Vertical (VV) and Vertical-Horizontal (VH) polarized SAR data for Mango during the year in study districts were recorded and backscattering signature wasgenerated.

Considering the accuracy of SAR data in phenological variations of the growing period, temporal features of study districts were extracted on geocoded time-series intensity images using multi-temporal dB images of VV and VH polarizations. The multi-temporal features viz. Max, Min, Mean, Max Date, Min Date and Span Ratio were generated using the acquisitions during 2018. MTF was extracted to delineate the mango area using the feature extraction tool of MAPscape software.

The estimated Mango area in Dharmapuridistrict was 8015 ha while in Krishnagiridistrict,it was 31118 ha and in Salem district, it was estimated to be 4852 ha (Figure 2). The estimated area through remote sensing method was compared with the Directorate of Economics and Statistics (DES) reported area for 2018, which revealed a deviation of -13.58 percent in Krishnagiri district, 0.84 percent in Dharmapuri district and -0.39 percent in Salem district (Table 1)..

Accuracy assessment: The mango area delineated using MTF (Multi-temporal Feature Extraction) method from SAR data was validated with the leftover 40 percent of the ground truth points. Around 93 Mango points and 24 Non-Mango sites were used to build the accuracy assessment through the confusion matrix (Table 2). The results of the confusion matrix revealed that, the overall accuracy of the mango map was 85.5 percent with a producer accuracy of 86.0 percent and Users accuracy of 95.2 percent for mango crop and it was 83.3 percent and 60.6 percent as producers and user's accuracy in non-mango areas respectively. Overall reliability of the produced map accounted to 85.5 percent. Average accuracy accounted to 84.7 percent and the average reliability was 77.7 percent for the mango area. Quality of the classification was assessed by the kappa index, which was 0.71 for homogenous, large, small and fragmented mango orchards present in the study district, which showed a good agreement for the estimation. Similar results for sugarcane and non sugarcane area was reported by Nithyaet al., (2019) using a regression model for classifying Lands at images and SAR data respectively. A Kappa index of 0.78 was achieved from the study and the results are from processing optical images, indicating the possibility of improving the accuracy level of area estimation by combining

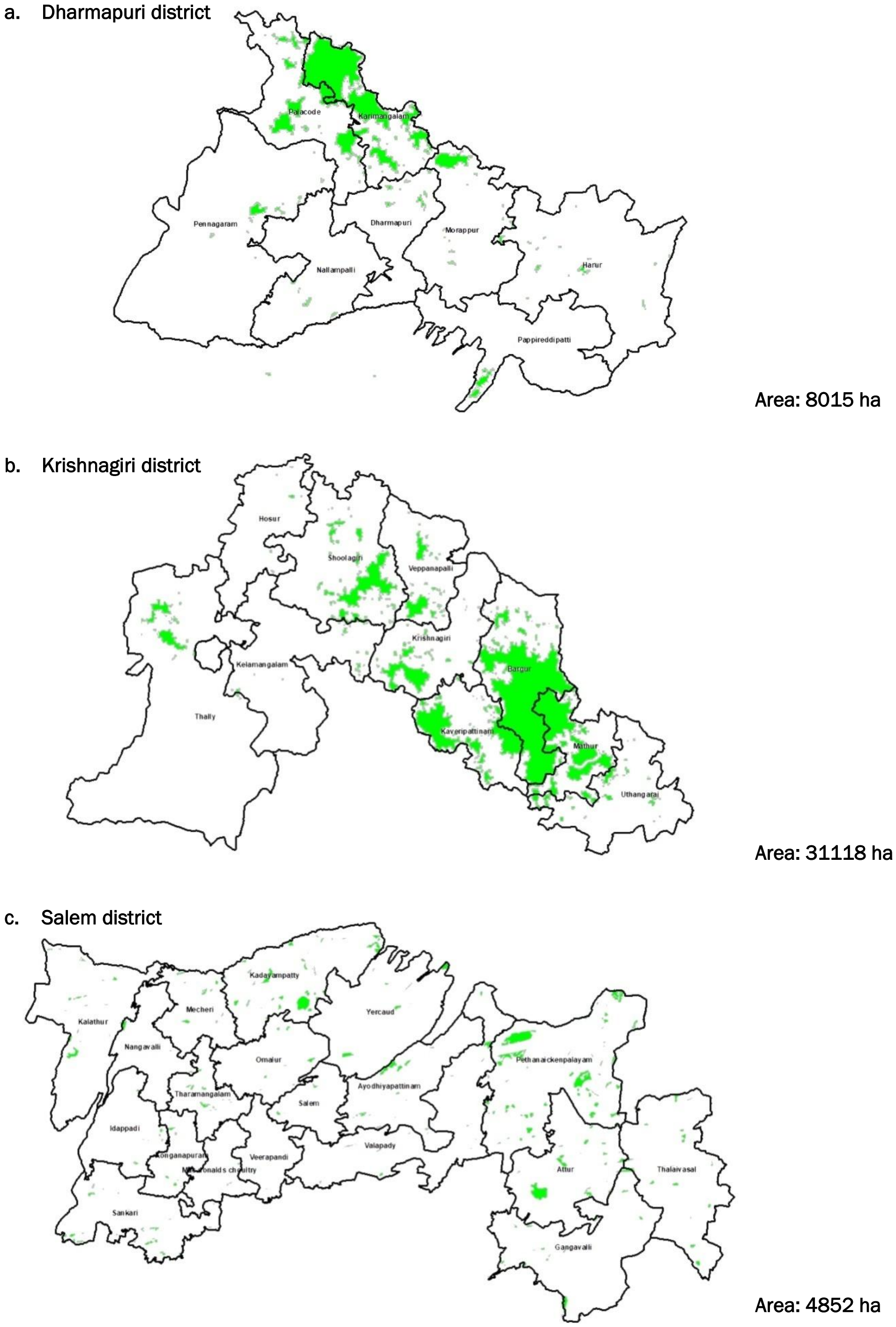

Figure 2. Mapping of Mango area depicted with block boundary

optical data with SAR data (Adamiet al., 2012) thereby overcoming the problems of climatic interference.

CONCLUSION

The identification of mango plantations and estimation of the area was accomplished from SAR satellite data with reliable accuracy in the study area revealing the possibility of using SAR data for plantation identification. The unavailability of optical data for crop area estimation during extreme weather conditions and cloud cover could be conquered using SAR data. Although the accuracy attained in the study was good, there is still a chance to increase by combining optical with SAR data which is evident from literature where mango area estimation accuracy from optical data was higher compared to SAR data (Kumar et al.,2016) . Hence the integration of optical and SAR data has to be tested in crop identification and area estimation to attain higher accuracy.

ACKNOWLEDGMENTS

The authors thank the Tamil Nadu Agricultural University for providing the fund to carry out the research work in a project mode and also thank the Professor and Head and staff of the Department of Remote Sensing and GIS, TNAU for their valuable comments and constructive suggestions on the manuscript.

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