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Crop Mapping using SAR Imagery: An Review

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Abstract: Agriculture is the backbone of Indian economy & is the pivotal sector for ensuring food security. Timely availability of information on agricultural crops is vital for making well versed decisions on food security issues. It is very important for national government to know what type of crops are being grown in which region in the current growing season, which will be useful in budget planning for import & export of food products. Traditional ground survey method is laborious, time consuming & expensive. Along with this, continuous monitoring of crops is highly difficult. Crop area estimation is a key element in crop production forecasting and estimation. The efficiency of crop area estimation using satellite imagery depends on the accuracy of crop classification.

Keywords: SAR images, image preprocessing (de-speckling), segmentation, feature extraction, crop classification.

1. INTRODUCTION

Identification of crop types is the first step of crop monitoring system & yield estimation. The traditional ground survey methods is difficult to acquire annual crop information due to less economic efficiency and some features of agricultural production for eg., the large coverage, the strong seasonal, strong spatial heterogeneity. The knowledge of the crop area is a key element for the estimation of the total crop production of a country and therefore the management of agricultural commodities markets. Remote sensing technology is feasible and effective way to solve this problem. It has been effectively used for crop identification and yield estimation. Remotely sensed images are invaluable to acquire geospatial information about earth surface for the assessment of land resources and environment monitoring.

Remote sensing is in general defined as the process of acquiring information about an object, area or phenomenon without being in physical contact with it. Remote sensing is most often understood as a means of data acquisition with the use of airplanes, balloons and satellite systems with subsequent processing & interpretation.

Remote sensing instruments are of two primary types—active and passive.Active sensors (Microwave Remote sensing), provide their own source of energy to illuminate the objects they observe. An active sensor emits radiation in the direction of the target to be investigated. The sensor then detects and measures the radiation that is reflected or backscattered from the target. Passive sensors (Optical Remote sensing), on the other hand, detect natural energy (radiation) that is emitted or reflected by the object or scene being observed. Reflected sunlight is the most common source of radiation measured by passive sensors [1,2]. The four major differences between Microwave remote sensing and optical remote sensing are as follows. Firstly, the most obvious difference from optical remote sensing is its capability to penetrate clouds and to some extent rain. Secondly, microwave is independent of the sun as a source of illumination, so it has the ability of all-day working. Thirdly, microwave is able to penetrate deeper into vegetation than optical waves can, so, when it is used to monitor vegetation, not only can acquire the surface information of the vegetation, but also can have some reflection of the vegetation leaves, stems, branches, stem and other structure information under the surface of vegetation. Fourthly, the received signal by the microwave sensor is mainly affected by the structural characteristics and dielectric properties of the surface features, so this information can reflect the surface features of the objects which may vary from the optical remote sensing reflect. Few of the SAR images applications are Monitoring of Kharif Crops, early detection of drought, flood mapping as part of disaster mining and relief operation, large area soil moisture mapping as input to Hydrological applications (drought and flood), in forestry for Biomass estimation (also forest density and type), in terrain analysis for accurate DEM generation, Land movement (for earthquake studies and land subsidence), in oceanography for Sea State, Waves, Oil Spills, Coastal Bathymetry. Further SAR images can used to carry out preliminary studies on snow / ice mapping, mapping of Surface and sub-surface structures, aquifers, mineralogy (related to geology domain) [3].

Following are the various image processing techniques to be performed on SAR images:

Image Acquisition: In this image will be acquired from Satellite by mentioning the longitude & latitude of the land region i.e., SAR images from Landsat8 or Awifs or LISS4 which will be used as an input for mapping of different crops.

Image Preprocessing (De-speckling): It is the technique for improving picture quality prior to computational processing and also used to remove the low frequency noise, reflections and masking portions of the images. SAR images contain some unwanted noise called speckle, which may causes difficult in interpretation. So de-speckling must be done before interpretation.

Segmentation: segmentation is the process of partitioning the digital image into multiple parts/segments. Segmentation process not only reduces the complexity of data but provides blobs containing only one object of interest/crop for analysis.

Feature extraction: After the segmentation process, various features are extracted from the vegetation indices of crops .The features which are commonly extracted for crop mapping are the texture & structural features of individual crops.

Image Classification: It is most important part in digital analysis. Classification can be executed on spectral features like density, texture etc., and then divides the features space into many groups (each representing different crop type) using various machine learning algorithms.

II.LITERATURE SURVEY

In agriculture domain, the common approach used by the government (farmers) for crop monitoring is to go to the field & acquire the images using cameras for estimation of the crop yield. So in this context a fast, reliable & automated system is required which provides the exact crop mapping & roughly yield estimation of various crops using SAR images as an input.

Omkar et.al, (2008) [4] applied Artificial Intelligence for classification of crops using Quick bird multispectral images of resolution 2.4m. They used four types of crops for classification namely Sugarcane, Ragi, Paddy & Mulberry on the basis of pixel values. Classification of crops was carried out using three different classifiers namely Maximum Likelihood Classifier (MLC), Ant Colony Optimization (ACO) & multilayer perception Neural Network trained using Particle Swarm optimization (PSO). They achieved 86.59%, 98.002% and 98.002% accuracy with MLC, MLP trained using PSO and ACO classifiers respectively.

Vijaya Musande et al., (2012) proposed Cotton Crop Discrimination Using Fuzzy Classification Approach. They have used temporal AWIFS and LISS III datasets of different months according to the life cycle of cotton crops. They investigated five spectral indices like Simple ratio (SR), Normalized Difference Vegetation Index (NDVI), Transformed Normalized Difference Vegetation Index (TNDVI), Soil-Adjusted Vegetation Index (SAVI) and Triangular Vegetation Index (TVI) using temporal multi spectral images. Among these classification, the comparison study shows that SAVI provides improved vegetation signals (highest fuzzy) of accuracy 93.12% [[5].

Y Murali Mohan Babu et al., (2011) have proposed Bayesian denoising of SAR image. Since SAR images are corrupted by a speckle which results in problems for interpreting the data. The main purpose of denoising is to remove the noise by maintaining Structural features & texture information of the scene. They have used various wavelet techniques for comparison of denoising of SAR images like Haar wavelet, Db4 wavelet, Sym wavelet &Bior wavelet with 0.1 variance. The simulation results using the number of standard test images have shown that the performance of Signal-To-Noise Ratio is better than that of soft & hard thresholding methods [6].

Pazhanivelan et al., (2015) have proposed Rice Monitoring & Yield estimation using Multi-temporal X-band SAR Single Look Complex (SLC) data obtained from the Italian Space Agency (ASI/e-GEOS) for COSMO-SkyMed (CSK) data and from InfoTerra GmbH for TerraSAR-X (TSX) data. They used high resolution (3m) SAR images to map & monitoring rice growing areas in Tamilnadu, India for three different sites. Multitemporal X-band, HH-polarized SAR images have been classified using the simple Rule-based classification for mapping rice areas.With 20 paddy fields, 32 total number of images with foot print area have been acquired with 12 to 15 days revisit of satellite. In the observation for mapping they considered plant height, water depth, weather condition crop stage & Leaf area Index. Simultaneously they compared the results with farmers & they got 87-92% overall accuracy with Kappa score from 0.73 to 0.85.Yield estimation has been done using ORYZA2000, a crop growth simulation model. This model involves input data such as daily weather data, soil properties, rice variety & water availability etc. They achieved 87% at district level & 85-96 % of accuracy t block level [7].

Chenghai Yang et al., (2011) have used SPOT 5 satellite imagery for crop identification. They used two images of pixel size 20m & 30m which covers different growing stages of variety of crops like Corn, Cotton, Sorghum & sugarcane. They have used SPOT 5 multispectral images which covers 60km by 60km area in South Texas. At first binary classification has been performed namely crop & non crop. Five different supervised classification techniques have been used namely Minimum Distance, Mahalanobis distance, Maximum Likelihood, Spectral angle Mapper (SAM) & Support Vector Machine (SVM). After the analysis, it has been concluded that the performance of SVM (91% accuracy) & Maximum likelihood (87% accuracy) are better than the other classifiers [8].

Zia ulQayyum (2013) have worked on optimal feature extraction Technique for crop classification using aerial imagery. They selected four crops namely olive, potato, wheat & sugar beet for the regions of Netherland & Pakistan. They considered two data sets & images have been preprocessed using ERDAS software & preprocessed images are segmented into regions containing individual crops. After segmentation, RGB images have been converted into gray scale to resize the images. A combination of WEKA & MATLAB is used for classification activities. Statistical, Texture, Discrete Cosine Transformation (DCT) & Discrete Wavelet Transformation (DWT) are used for feature extraction. Results of these features shows that DWT & DCT are more accurate than other feature extraction techniques. They achieved 96% accuracy with DWT & 90% with DCT [9].

S.M Tavakkoli (2008) have proposed Monitoring Agricultural activities using Multi-Temp oral ASAR Envisat Data. A time series of dual polarization (VV/HH) of Envisat ASAR data is used for analysis. For some crop types polarimetric SAR imagery is highly correlated & it has been proven to be better suited for classification task because of its all-weather capability & data acquisition on regular basis. Radar data can be acquired more frequently than optical data. Hence multi temporal radar data are commonly used for monitoring of Agricultural activities. Fuhrberger Field located at north of Honavar, Germany is selected as ground truth samples. Initially monthly coverage by Envisat satellite is planned, simultaneously Ground survey were conducted during the time of satellite overpass. They acquired 11 pairs of data during Nov 2003 until Nov 2004 which are of pixel spacing of 12.5m. Images have been processed into geocoded products & Azimuth direction. During ground survey, relevant features of the status of the fields were observed & collected such as usage, treatment pattern & additionally vegetation coverage, color, irrigation, fertilizers etc., have been stored into GIS.Multi temporal classification is assumed to be beneficial due to the changeable nature of Agricultural fields. Each crop has its own specific growth period & phenology & therefore can be separated from others. Lea, Fallow, Strawberry, Sugar beet are the crops used under study. Speckle in SAR reduces classification accuracy, therefore various filters used for investigation are Lee, Lee-sigma & Median filters varies 84.3% to 86.5%. Images filtered by Median filter results in best value of accuracy 86.5%. The various classification techniques used are Maximum Likelihood Classifier (MLC), Minimum Distance, Mahalanobis distance (MD) & Support Vector Machine (SVM). MLC & SVM perform best in the classification of multi temporal SAR data sets. SVM classifier (84%) is more accurate than MLC (79%) [10].

Yanga et al (2011)worked on the crop identification by using SPOT 5 satellite imagery. They used two images of pixel size20m and 30 m which cover variety of crops of different growing stages. A SPOT 5 multispectral image scene covering a 60 km by 60 km area in the Rio Grande Valley of south Texas was acquired while images were taken during the discrimination period for a given region. At first stage, binary classification was performed namely crop and non-crop, which again was categorized into sub-classes. Sub-classes of Crop included corn, cotton, grain, sorghum and sugarcane while non-crop class contained grass (forage), mixed herbaceous species, mixed woody specie, fallow and water. They employed five supervised classification techniques, which were minimum distance, Mahalanobis distance, and maximum likelihood, spectral angle mapper (SAM) and support vector machine (SVM). They analyzed that performance of SVM and maximum likelihood was better than other classifiers. The accuracy of SVM was 91% and maximum likelihood was 87%.They increased the pixel size 10m to 20m or 30m which did not cause any imperious effect in the accuracy results [11].

Bischof H Wet al (1992) proposed a study of Multispectral Classification of Landsat images using Neural Network. In this they classified Landsat TM data on pixel-pixel basis using three-layer back propagation neural network. The data used for training and testing of the classification accuracy of the neural network were selected from a section (512 x 512 pixels) of a Landsat TM scene of the surroundings of Vienna. The aim of the classification with the neural network was to distinguish between the four categories: built-up land, agricultural land, forest, and water. Moreover, a method based on the neural networks for the post classification smoothing was also presented & shown to be superior to conventional majority based filters. They compared their results with the Gaussian Maximum Likelihood classification and reported the performance of neural network is better than the maximum likelihood classifier. Classification accuracy by the neural network was 91.0% which was better than the weighted majority filter whose accuracy was 89.1% [12].

Beeresh H V et al (2014) used an approach for identification & classification of crops using multi spectral images. They used Landsat 8 Enhanced Thematic Mapper plus (ETM) images of coconut in Tumkur District, Karnataka, with 30m resolution and six spectral bands. The image was preprocessed & resampled at 25m resolution. They employed Spectral Mixture Analysis (SMA) to use mixed pixel approach. According to SMA each pixel is made up of number of varied spectral types. It is the key point that measures the percentage of spectra in each land cover type for each pixel. SMA uses linear mixture model which can be applied to six band Landsat image. Then Digital number can be obtained and converted into satellite radiance values using Gain & Bias values. They have used various classification algorithms for crop identification and multi temporal change detection. In this study, three different classification algorithms were performed for crop identification and multitemporal change detection. The first two of them are ISODATA unsupervised classification and Minimum distance supervised classification techniques which are two main pixel based classification algorithms and the last one is the object based classification algorithm for classifying coconut, water body, non-crop and mixed crop region. They achieved 83.33% accuracy by using SMA of Digital Number (DN) values, while it was 88% for SMA of radiance values [13].

M MUstuner et al (2014) worked on Crop type Classification using Vegetation Indices of Rapid eye imagery. In this study they have used 3 different vegetation indices, the Normalized Difference Vegetation Index (NDVI), the Green Normalized Difference Vegetation Index (GNDVI) and the Normalized Difference Red Edge Index (NDREI) of Rapid Eye imagery on crop type classification as well as the effect of each indices on classification accuracy were investigated. RapidEye is the first high resolution multispectral satellite system incorporating the red- edge band which is sensitive to vegetation chlorophyll content. Spectral vegetation is widely used for crops evaluation. RapidEye data provides 5 spectral bands with 5m resolution. Data was delivered in level 3A (orthoproduct) in which radiometric, sensor & geometric corrections have been applied to the data. Four different sets of spectral features have been used for analysis of the potential use of vegetation indices. They results of SVM with three vegetation indices algorithms shows that NDREI has more accuracy than other two for crop classification [14].

Rajesh K Dhumal proposed classification of crops from remotely sensed images. The major work of this paper is the selection of suitable satellite data (multi spectral & hyper spectral) for classification of crops. Multispectral images give much detail for overall vegetation mapping in large area. Selection of spectral bands in hyper-spectral images is also quite challenging task. Hyper-spectral images perform well. They used supervised & unsupervised classification. Unsupervised classification is a clustering analysis in which pixel are grouped into certain categories in terms of the similarity in their spectral values. During post processing each spectral cluster get linked to meaningful label related to actual ground cover. In Supervised classification the Analyst should aware about ground cover. Process of supervised classification involves the selection of appropriate band with definition of signature for training samples. These signature forms foundation for subsequent classification. They compared the two satellite images with various classification techniques like Sequential floating forward selection, SVM, neural network & K-NN classifier for classification of crops. Finally multispectral images give much detail for overall vegetation mapping in large area, whereas hyper spectral images perform well in differentiating similar crops [15].

NataliiaKussul et al (2014) worked on the use of Satellite imagery to crop classification in Ukraine with JECAM project. In this they have used multitemporal SAR (RADARSAT-2) images for summer crop classification purpose. Three classificationsnamely neuralnetwork, Support Vector Machine (SVM) & Decision Tree (DT) have been adopted for classification of crops. Urkaine is one of the most developed country that is the sixth largest wheat exporter. The major crops used are maize, soya bean & sunflower. They used feed forwarded neural network also referred to as Multilayer perception (MLP) with logistic outputs and cross entropy error function that was minimized using the quasi-Newton algorithm. An important property of SVMs is that the determination of the model parameters corresponds to a convex optimization problem, and so any local solution is also a global optimum. A decision tree classifier is built from a set of training data using the concept of information entropy. Classification was performed on a per-pixel basis. The comparison study shows that MLP (80.4%) is better than SVM (78.6%) &DT (78.1%) [16].

Zhang G J (2013) proposed a range of Feature Extraction Techniques (such as Statistical, Texture, DWT and DCT), having a vital role in crop classification, for classifying crop images from regions of Netherlands and Pakistan. Pre-processing techniques were followed by resizing of each image and subsequent division into blocks followed by different features extraction techniques including Statistical, Texture Feature Extraction, DCT and DWT were employed. These feature extraction techniques have been evaluated using various classifiers namely: Support Vector Machine, Naïve Bayesian, K Nearest Neighbor, Decision Tree and ensemble based classifiers. The results of classifiers on DCT features were better than accuracy of Statistical and GLCM texture features. KNNC gives the better results with 90% accuracy on DCT features [17].

Elizabeth Heller et.al(2012) have worked on Mapping crop types & cropping intensities in heterogeneous landscapes of southern India using Multi-temporal medium resolution Imagery. The study area encompasses the entire catchment of the Malaprabha River in the Belgaum district of Karnataka, India. In this study they used satellite image from Resourcesat-1(IRS-P6) with 23.5 m resolution which includes four bands Red, Green, Near infrared and mid-infrared .Images were geo rectified in ArcGIS using first order polynomial equation fit to ground control points obtained from survey of topographic maps. They used a stacked hierarchical procedure to create three nested level (a) single rainfed paddy rice versus continuously irrigated sugarcane, (b) irrigated versus rainfed areas, and (c) multiple cropping. All four bands from each of the three images dates were stacked & a Gaussian Maximum Likelihood classifier were used to conduct three supervised classification. The first objective of their study was to distinguish two key crop types: a single crop of rainfed paddy rice from irrigated and full-year crops such as sugarcane and yielded an overall accuracy of 89 percent with a kappa index of 0.81. The Second objective was, to distinguish irrigated from rain fed are and yielded an overall accuracy of 74.6 percent and a kappa coefficient of 0.63. The third objective was to determine the extent of multiple cropping(Single Rainfed (Paddy) ,Full-year Irrigated (Mostly sugarcane) ,Double Irrigated,(Paddy/Other) ,Double Irrigated, Single Rainfed ,Double Rainfed (Paddy/Other),Double Rainfed, Perennial Rainfed (Orchard) ,Grassland)within the basin and the overall accuracy of the nine-class map was 60.1 percent with a kappa coefficient of 0.52 [18].

The survey of classification of crops acquired suing SAR images is summarized in table 1.

Table :. Survey of Classification of crops acquired using SAR images

Author Name	Class types	Satellite Image	Techniques
Omkar et al 2008[4]	Sugar cane, Ragi, Paddy & Mulberry	Multispectral image of resolution 2.4m	3 types of classification algorithms Maximum Likelihood classifier (86.59%), Particle Swarm Optimization (98.27%), Ant Colony Optimization (98.002%)
Vijaya B. Musande [5]	Cotton	Landsat 8 multispectral temporal data	K means clustering with Kappa Coefficients with accuracy 95%
Y Murali Mohan Babu [6]	General crops	SAR images	Wavelet Techniques for comparison of denoising of SAR like Haar, Db4, Sym&Biorwaveltet with variance 0.1.Results shows SNR is better than soft & hard thresholding.
S. Pazhanivelan et.al [7]	Rice	Multi-temporal COSMO Skymed, TerraSAR -X With 3m resolution	Rule based classification for mapping with 87 to 92% accuracy & Yield estimation is done with ORYZA2000 a simulation model with the accuracy of 85 to 96% accuracy.

Changhai Yang et al [8]	Corn, Cotton, Sorghum& sugarcane	SPOT 5 images of pixel size 20m & 30m	5 supervised classifications namely Minimum distance, Mahalanobis distance Maximum likelihood, Spectral angle Mapper & SVM with SVM 91% & ML 87% accuracy.
Zia UlQayyum [9]	Olive, Potato, Sugar Beet, Wheat, Barley	Remote Sensing Satellite images	Feature Extraction Techniques like Statistical, Texture, DCT, DWT with DCT 90% & DWT 96%. classification Techniques like Neural Networks, Decision tree, KNN
S M Tavakkali [10]	Lea, Strawberry, Sugar beet, Potato	Multi temporal ASAR ENVISAT data 12.5m	Various Filters like Lee-Sigma, Lee & Median filters with 86.5%
Yanga et al [11]	Corn, Cotton, Sorghum & Sugar cane.	SPOT 5 Multispectral image 20m & 30m pixel size	First binary classification was performed namely crop & non crop. Five supervised classification techniques Minimum distance, SVM, Maximum likelihood, Mahalanobis distance & Spectral Angle Mapper. The accuracy of SVM was 91% & Maximum likelihood was 87%.
Bischoff et al [12].	built-up land , forest, water, agricultural area	Landsat multispectral image	They have used pixel-pixel basis using back propagation neural network. They compared their results with the Gaussian Maximum Likelihood classification and reported the performance of neural network is better than the maximum likelihood classifier. Classification accuracy by the neural network was 91.0% which was better than the weighted majority filter whose accuracy was 89.1%.
Beeresh H V [13]	Coconut, water body, mixed crop and non-crop	Lansat-8 with 6 spectral bands at 30m resolution	Spectral Mixture Analysis is an alternative approach which uses mixed pixel approach. Three different classification algorithms were performed for crop identification and multitemporal change detection. Namely ISODATA unsupervised classification and Minimum distance supervised classification techniques which are two main pixel based classification algorithms and the last one is the object based classification algorithm. Comparison study shows that SMA (88%) based classification gives more accurate results than others (83.33%)
M Ustuner et al [14]	Aegean region of Turkey Corn, Cotton	RapidEye high resolution multispectral incorporating red edge band	They have used 3 different vegetation indices namely NDVI, GNDVI & NDREI. Comparison study between various NDVI with SVM shows that vegetation indices derived from original spectral bands could be used for efficient classification
Rajesh K Dhumal et [15]	Selection of Satellite data which suits for crop classification	Awifs, SPOT 5, Landsat	Selection of satellite data that suits for crop classification i.e, Multispectral and Hyperspectral. SVM, neural network & K-nn classifier are used for classification of crops
NataliiaKussul et al [16]	Summer/winter crops maize, Sugar beet soya bean & sunflower (in addition classification of Other crops ,villages, Forest Grassland and Water)	Multi temporal RADARSAT-2 SAR image	They have taken SAR images & classified using three classifiers namely neural network, Support Vector Machine & Decision Tree. Comparison study shows Multilayer perception (80.4) is better than SVM (78.6%) & DT (78.1%).
Zhang G J [17]	Olive, Potatoes, Sugar beet and wheat	Satellite imagery collected is pre-processed by using ERDAS IMAGINE software	Different features extraction techniques including Statistical, Texture Feature Extraction, DCT and DWT were employed followed by classification using Support Vector Machine, Naïve Bayesian, K Nearest Neighbor, Decision Tree and ensemble based classifiers. The results of classifiers on DCT features were better than accuracy of Statistical and GLCM texture features. KNNC gives the better results with 90% accuracy on DCT features
Elizabeth Heller et al [18].	Sugar cane, paddy. (also classified water body, irrigated land, grassland,	Multi temporal medium resolution LISS III (24m) with 4 bands Green, Red,	They used a stacked hierarchical procedure to create three nested level (a) single rainfed paddy rice versus continuously irrigated sugarcane, (b) irrigated versus rainfed areas, and (c) multiple cropping..

	rain fed area)	near Infrared & mid infrared.	

III . CONCLUSION

In recent years, crop identification and area monitoring using SAR data is being given more and more attention. To some extent, SAR data has the advantage that cannot influenced by the rain and cloud weather and can penetrate crop in a certain range and the merits make a great contribution to the prevailing trend when compared with the optical images. This paper provides survey of research findings of applications of SAR images for crop classification using various classifiers.

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