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P Christy Nirmala Mary
Agricultural College & Research Institute, Madurai, Tamil Nadu, India

S Pazhanivelan
Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Correspondence
P Christy Nirmala Mary
Agricultural College & Research Institute, Madurai, Tamil Nadu, India

Monitoring and yield assessment of rice through geospatial technologies in Cuddalore district, Tamil Nadu

P Christy Nirmala Mary and S Pazhanivelan

Abstract

Droughts and floods are water-related natural disasters which affect a wide range of environmental factors and activities related to agriculture, vegetation, human, wild life and local economics. Floods are among the most devastating natural hazards in the world, claiming more lives and causing more property damage than any other natural phenomena. Rice is the most important cereal crop governing food security in Asia. Accurate and consistent information on the area of production is necessary for national planning and policy taking decision. Remote sensing has the scope for cost effective precise estimates of rice area to give insurance policy to the farmers affected by flooding. The RIICE project - Remote Sensing Based Information and Insurance for Crops in Emerging Economics tested SAR – Synthetic Aperture Radar based mapping of rice area in Cuddalore district, samba season from mid July 2013 to the first week of January 2014 was monitored. The yield was estimated using ORYZA 2000, a crop growth Simulation Model developed by IRRI (Boumman *et al*., 2001). In the rice area map generated for Cuddalore, variability in rice crop establishment data was due to the uncertainty in the date of water availability. The Rice Map accuracy was 92 % and Kappa value was 0.85. Rice yield accuracy was 99 %. The Rice estimate (kg/ha), Crop Cutting Experiment (kg/ha), RMSE (kg/ha), NRMSE (%) and accuracy (%) values were 3816, 3854, 38167, 1.0 and 99.0 respectively. The simulated yield matched observed yield perfectly indicating the suitability of these products for policy decisions ensuring food security besides reducing the vulnerability of small holder rice farmers in India.

Keywords: rice, food security, sar, yield estimation, oryza, cosmo skymed, terra sar-x

Introduction

Rice accounts for a significant contribution to the total food grain production in India. As the rice production area either stabilizes or declines, and there is a wide gap between projected demand and current level of production. Agriculture is inherently sensitive to climate conditions and is among the sectors most vulnerable to natural disaster. In simple terms, according to Sivakumar (2005) [8], a natural disaster is a natural event with catastrophic consequences for living things in the vicinity. Floods are among the most devastating natural hazards in the world, claiming more lives and causing more property damage than any other natural phenomena. Rice is the most important cereal crop governing food security in Asia. Accurate and consistent information on the area of production is necessary for national planning and policy taking decision. Remote sensing has the scope for cost effective precise estimates of rice area to support, augment, improve or even replace survey and statistical methods (Gumma *et al*., 2014) [3]. Rice cultivation during the monsoon season (Huke and Huke, 1997) [4] which has wide cloud cover (NASA, 2014) [6], wide range of conditions and environments, small land holdings and diverse and mixed cropping systems (Nguyen *et al*., 2012) [7] are the most challenging factors in limiting the use of remote sensing as tool for rice crop monitoring. Synthetic Aperture Radar (SAR) imagery is a promising option to overcome the issue of cloud cover and substantial research evidences are available on the suitability of SAR for rice crop mapping in the region. Rice detection algorithms should be general and robust to suit wide range of practices and environments (Boschetti *et al*., 2014) [1] ranging from irrigated to rainfed rice with different maturities (Maclean *et al*., 2013) [5] and establishment practices, such as direct seeding or transplanting. The complex rice environments require high resolution imageries and high-frequency acquisitions. Recent and planned launches of SAR sensors coupled with state-of-threat automated processing can provide sustainable solutions to this challenge to map and monitor one of the world‘s most important crop. The objective of this study is to test a method of rice area mapping using a rule-based classification and parameter selection approach across multiple sites based on the agronomic knowledge on temporal development of rice crop under different conditions and its management in relation to backscatter. The far-reaching goal is to demonstrate that SAR based operational mapping of rice crops across a diverse range of environments with multi-temporal SAR data and yield estimation by integrating these products into the ORYZA crop growth model.

Materials and Methods

Multi-temporal X-band SAR Single Look Complex (SLC) data were obtained from the Italian Space Agency (ASI/e-GEOS) for COSMO-SkyMed (CSK) data and from InfoTerra GmbH for TerraSAR-X (TSX) data. In both the cases, data were obtained in HH polarization with consistent incidence angles in each multi-temporal stack, ranging from 41 to 44 degrees across sites. A large incidence angle is preferred, because (i) wind effects on water (in particular, during land preparation prior to transplanting) are significantly decreased, (ii) the dynamic of the radar backscatter is larger and (iii) the spatial resolution is higher. The image acquisition dates, locations, mode, pixel size, polarization and incidence angles are shown in Table 1. Image mode, extent, pixel size, polarization and incidence angles were constant for each footprint. CSK data are available from four X-band HH-SAR satellites with a 3.12-cm wavelength and a 16-day revisit period for the same satellite with the same observation angle. CSK data on Strip map mode (3-m resolution) was used at two sites with a footprint of 40 × 40 km.

Table 1: SAR data acquisition summary: locations, dates and modes used for 2013 Samba season.

Site No.	Start and end dates	# of images Satellite	Scene center, area (sq km)	Mode, resolution (m)	Polarization, angle (°)
Tamil Nadu, Cuddalore	10	CSK	11.74°N79.56°E, 1,600	Stripmap, 3	HH, 44

Field observations were performed throughout the season in up to 20 paddy fields (Table.1) within each footprint. These fields were selected, with the farmer's consent, prior to the start of the rice season and the image acquisition schedule. Observations were made on or as close to the image acquisition date as possible. Observations included latitude and longitude from handheld GPS receivers, descriptions and photos of the status of the field, plant height, water depth, weather conditions, crop stage and leaf area index (LAI). The same field data collection protocols were used at all sites. LAI measurements were taken only during visits between seedling and flowering stages, and these were recorded non-destructively using AccuPAR LP-80 Ceptometer (Decagon Devices, Inc., Pullman, WA, USA). At the end of the season, the farmer was interviewed to collect information on the rice variety, water source, crop management and establishment practices, as well as inputs, such as pesticide and fertilizer. A rapid land cover appraisal method was adopted to collect land cover information at approximately 100 locations throughout each footprint with these points split 50/50 between non-rice points and rice points. Rice is the dominant crop among the three RIICE sites in India.

In Cuddalore District, the samba season from mid-July 2013 to the first week of January 2014 was monitored. Rice fields in this district are predominantly under a well irrigation system; hence, most of the chosen locations were irrigated. The popular rice varieties grown were CR1009, BPT5204 and White Ponni, with maturity duration ranging from 135 to 160 days. Both transplanting and direct seeding of rice are common in this district, with the former establishment method being more dominant. The SAR time-series data underwent a series of basic processing steps to generate terrain-geocoded $\sigma°$ values suitable for analysis. This multi-temporal stack was analyzed using a rule-based classifier to detect rice areas. A standard confusion matrix was applied to the rice/non-rice validation points collected at each site. The overall accuracy of the rice/non-rice classification and the kappa value were recorded. The accuracy assessment was a comparison of the classified rice map against ground-truth data. The spatial resolution of the rice maps ranged from 3 m to 15 m. However, the ANLD filtering processes reduced the effective resolution by performing locally adaptive smoothing and edge detection. The yield was estimated using ORYZA2000, a crop growth simulation model developed by IRRI (Boumman *et al*., 2001). The simulations account for water and nitrogen dynamics based on climatic, soil conditions and management practices. Irrigation and nitrogen fertilizer inputs are assumed as recommended for achieving attainable yield.

Results and Discussion

Rice area maps

Figure 1 shows rice area maps derived from multitemporal X-band SAR imagery for rice area map generated for Cuddalore, variability in rice crop establishment date was due to the uncertainty in the date of water availability. The clearly demarcated patches in the rice crop in the northern part are water tanks that were successfully excluded from the classification.

Rice map accuracy assessment

The accuracy assessment for the rice maps was conducted on a rice/non-rice basis, where all other land cover types were grouped into a single non-rice class.

Table 2: Summary of site visits and observed rice crop characteristics during the monitored seasons.

Site No.	Study site	Validation points and date(s) of validation	Rice area (ha) and as % of footprint	Accuracy and Kappa
1	Tamil Nadu, Cuddalore	111, 12-02-2014 and 03-03-2014	26,015, 16%	92%, 0.85

Rice yield estimation

The yield was estimated using ORYZA2000, a crop growth simulation model. The model estimated yield (Table 3) based on input data such as daily weather data, soil properties, rice variety, water availability and crop management practices. At district level an accuracy of 99% (Table 5) was achieved in Cuddalore. At block level it was interesting to come across an accuracy of 85-96% indicating the suitability of these products for policy decisions. At field level also, significantly higher accuracy was recorded for yield estimates derived using ORYZA model with Remote sensing based products indicating the scientific validation as compared to other methods of yield prediction. The study demonstrated that rice area could be accurately classified with X-band HH polarization SAR images across multiple environments and management conditions and rice yields could be estimated by integrating ORYZA model with Remote sensing based products. With the Current and forthcoming SAR systems, such as CSK, TSX and RADARSAT-2. The Rice Map accuracy was 92 % and Kappa value was 0.85. Rice yield accuracy was 99 %. The Rice estimate (kg/ha), Crop Cutting

Experiment (kg/ha), RMSE (kg/ha), NRMSE (%) and accuracy (%) values were 3816, 3854, 38167, 1.0 and 99.0 respectively (Table 3 to 6).

Table 3: Summary of rice yield estimates

S. No.	District	Riice estimate (kg/ha)
1	Cuddalore	3816
2.	Viluppuram	3786

Table 4: Rice yield estimates at block level

Block	District	RIICE estimate (kg/ha)	Block	District	RIICE estimate (kg/ha)
Cuddalore	Cuddalore	4064	Kumbakonam	Thanjavur	4892
Virudhachalam	Cuddalore	3542	Thanjavur	Thanjavur	5092
Panruti	Cuddalore	3763	Thiruvaiyaru	Thanjavur	4615
Kurinjipadi	Cuddalore	3667	Orattanadu	Thanjavur	5123

Table 5: RIICE CCE data vs. ORYZA2000 yield estimates at District level

Sl. No.	District	RIICE estimate (Kg/ha)	CCE (Kg/ha)	RMSE (Kg/ha)	NRMSE (%)	Accuracy (%)
1.	Cuddalore	3816	3854	38167	1.0	99.0

Table 6: RIICE CCE data vs. ORYZA2000 yield estimates at District level

Sl. No	Block	**RIICE estimate** (Kg/ha)	**CCE** (Kg/ha)	**RMSE** (Kg/ha)	**NRM SE** (%)	Accuracy
1.	Cuddalore	4064	3854	209433	5.4	94.6

Conclusions

The study demonstrates that regularly acquired X band HH SAR imagery is suitable for rice crop monitoring across the major rice environments of South and Southeast Asia. The classification is based on a temporal analysis of the spectral signature, including a detection of agronomic flooding at the land preparation and/or seedling stage followed by a rapid increase in biomass relative to the duration of the vegetative stage of the varieties in the footprint. Yield Simulation accuracy of more than 87% at district level and 85-96% at block level from the study means that simulated yield matched observed yield perfectly indicating the suitability of these products for policy decisions ensuring food security besides reducing the vulnerability of smallholder rice farmers in India.

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