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Estimating inter-annual diversity of seasonal agricultural area using multi-temporal resourcesat data

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ABSTRACT

The present study aims at analysis of spatial and temporal variability in agricultural land cover during 2005–6 and 2011–12 from an ongoing program of annual land use mapping using multidate Advanced Wide Field Sensor (AWiFS) data aboard Resourcesat-1 and 2.

About 640–690 multi-temporal AWiFS quadrant data products per year (depending on cloud cover) were co-registered and radiometrically normalized to prepare state (administrative unit) mosaics. An 18-fold classification was adopted in this project. Rule-based techniques along with maximum-likelihood algorithm were employed to deriving land cover information as well as changes within agricultural land cover classes. The agricultural land cover classes include – kharif (June–October), rabi (November–April), zaid (April–June), area sown more than once, fallow lands and plantation crops. Mean kappa accuracy of these estimates varied from 0.87 to 0.96 for various classes. Standard error of estimate has been computed for each class annually and the area estimates were corrected using standard error of estimate. The corrected estimates range between 99 and 116 Mha for kharif and 77–91 Mha for rabi.

The kharif, rabi and net sown area were aggregated at 10 km × 10 km grid on annual basis for entire India and CV was computed at each grid cell using temporal spatially-aggregated area as input. This spatial variability of agricultural land cover classes was analyzed across meteorological zones, irrigated command areas and administrative boundaries. The results indicate that out of various states/meteorological zones, Punjab was consistently cropped during kharif as well as rabi seasons. Out of all irrigated commands, Tawa irrigated command was consistently cropped during rabi season.

1. Introduction

A reliable national or global land use land cover (LULC) data set is the most sought information by various thematic and modeling experts for various developmental, environmental and resource planning applications to develop regional as well as global scale process models (Douglas, 1999; Chapin et al., 2000; Sedano et al., 2005). Further, monitoring spatial distribution of land cover changes is crucial for understanding links between policy decisions and subsequent changes in land use activity.

Globally various organizations have developed different classification systems based on the need of information and availability of resources/technologies. Attempts were also made to generate global land cover products (Table 1) viz., International Geosphere Biosphere Project DISCover at 1 km × 1 km resolution (Loveland et al., 2000), University of Maryland at 1 km × 1 km resolution (Hansen et al., 2000); Global Land Cover 2000 at 1 km × 1 km (Fritz et al., 2003) and MODIS Land cover product at 250 m × 250 m resolution (Zhan et al., 2000). Thus year 2000 can remembered for global land cover databases. Global scale land cover classifications

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Table 1
A glance on global land cover mapping.

Sl no	Land cover mapping	Year	Sensor used	Resolution	Number of classes	Reference
1	MODIS land cover	2000	MODIS-Terra	250 m × 250 m	17	Zhan et al., 2000
2	GLC2000	2000	Spot-Vegetation	1 km × 1 km	22	Fritz et al., 2003
3	AVHRR global land cover	1998	NOAA-AVHRR	1 km × 1 km to 1° × 1°	14	Scepan, 1999
4	Global map (GLCNMO)	2003	MODIS	1 km × 1 km	20	Tateishi et al., 2008
5	Glob cover	2005	MERIS	300 m × 300 m	22	Leroy et al., 2006

estimated (up to 17 classes) from Advanced Very High Resolution Radiometer (AVHRR) satellite data could give accuracies between 70% and 90% with an overall area weighted accuracy of around 67% (Scepan, 1999), while the land cover data set generated using MODIS is expected to have accuracy near 80% (De Colstoun and Walthall, 2006). However, there are well known limitations to achieve higher classification accuracies (Hansen et al., 2000). Recently Glob cover land cover estimated from MERIS data was available from European Space Agency at 300 m × 300 m resolution (Leroy et al., 2006). Most of these global data sets available are estimated from coarse resolution data sets and will be of immense use for global studies. For countries like India, which have fragmented land cover, these data sets have limited use.

In India, agricultural statistics are estimated generally from three methods of estimating crop area namely, complete enumeration method which is being followed in 17 states accounting to 85% of estimated area, followed by sample survey followed in 7 states accounting to 9% of estimated area and *ad-hoc* method in rest accounting to 5% of the reported area. Since most of the cropping patterns are more or less geographically stabilized, first cut information on net sown area will be very useful for taking stock of country's agricultural situation.

Studies so far conducted in India on LULC mapping and changes thereafter have limited scope to provide baseline data towards regional planning and evaluation especially due to limitation in these data sets to spatially represent the temporal dynamics in land cover. It was also noticed that temporally dynamic land use practices can only be monitored using temporal satellite remote sensing data (Townshend et al., 2001).

In India, attempts were made to characterize the land cover of India using coarse resolution data sets – SPOT-Vegetation sensor (Agrawal et al., 2003) and IRS-WiFS data sets (Joshi et al., 2006). However, the classification system adopted in the above two data sets is mostly oriented towards forest area sub-categorization with little emphasis on agriculture. The dynamics of agriculture land plays an important role in global climate change. Thus, the classification system adopted in this study reported here provides information about the seasonality of agriculture land cover classes and their temporal dynamics.

Nominal temporal frequency is an important consideration for studying land cover changes using remote sensor data (Lunetta et al., 2004). When the crop cover has staggered sowing and harvesting periods spread almost across the entire crop calendar year, it calls for very regular and systematic satellite data coverage to retrieve reliable information on land cover depicting the extent of crops in various cropping seasons. Thus the Advanced Wide Field Sensor (AWiFS) aboard Resourcesat (IRS-P6) of India offering moderate resolution data at 5-day interval has a good potential to map LULC at regional scale. Especially in the areas where there is an issue with cloud cover coupled with staggered agricultural operations AWiFS data with high temporal resolution coupled with moderate spatial resolution offers a good solution for land cover monitoring.

Decision tree classification techniques have also been used successfully for preparation of global land cover maps like MODIS land cover product (Strahler et al., 1999). These techniques have substantial advantages for remote sensing classification problems because of their flexibility, intuitive simplicity and computational efficiency (Friedl and Brodley, 1997). The added advantage with decision trees is that they make no assumption about the data distribution. As a consequence, decision tree classification algorithms are gaining increased acceptance for land cover classification problems, particularly at continental to global scales. Further, decision trees can be used to handle the complex nonlinear relationships in remote sensing data (Xu et al., 2005) and noisy and missing data (Quinlan, 1993). A variety of works have demonstrated that decision trees executed in supervised fashion provide an accurate and efficient methodology for land cover classification problems (Friedl and Brodley, 1997; Wen et al., 2008). By virtue of above mentioned advantages, in the present study decision tree classification method was used during initial two cycles to estimate a stable land cover output. Subsequently maximum likelihood classification was used to classify the individual monthly AWiFS mosaics and was combined with previous cycle's data through logical rules to estimate the agricultural land cover information.

The LULC output thus generated is being used as an important input into the crop planning, crop monitoring, fertilizer and irrigation management, assessing agriculture and soil carbon sequestration potential, forest cover monitoring, disaster damage assessment, environmental impact assessment and catchment studies that are being carried out in India by various organizations. Besides, it forms an important spatial variable in climate modeling. The temporal and spatial pattern of land cover helps in deriving climate resilience/adoption patterns. Currently the temporal land cover data sets of India are available at bhuvan.nrsc.gov.in under NRSC Open EO Data Archive (NOEDA) for registered users.

The work reported here will focus on the temporal variability in agricultural classes during the past 7 annual cycles during 2005–6 to 2011–12.

2. Data set

The Advanced Wide Field Sensor (AWiFS) data aboard Resourcesat series of satellites form the source data. The salient characteristics of AWIFS sensor aboard Resourcesat-1 and Resourcesat-2 is appended as Table 2. These data sets, supplied in quadrants each covering 360 × 360 km area, were acquired for the period August, 2004 to May, 2012 over entire India on monthly so as to cover the variability in agricultural operations for effective capturing of land cover information along with net sown area under various agricultural cropping seasons. About 640–690 multi-temporal AWiFS

Table 2
Specification of AWiFS sensors aboard Resourcesat-1 and 2.

Sl no	Characteristics	Resourcesat-1	Resourcesat-2
1	Swath (km)	740 km	740 km
2	Spectral bands (μm)	B2: 0.52–0.59 B3: 0.62–0.68 B4: 0.77–0.86 B5: 1.55–1.70	B2: 0.52–0.59 B3: 0.62–0.68 B4: 0.77–0.86 B5: 1.55–1.70
3	Spatial resolution (m)	56	56
4	Repeat cycle (days)	5	5
5	Quantization	10 bits	12 bits
6	Gain setting	Single gain setting	100% albedo; no gain setting

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