Evaluating use of remote sensing for identifying management strategies: Example for small plot farmers during the dry season in southern Bangladesh.

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Abstract

Farming in southern Bangladesh has traditionally depended on wet-season rice with large areas of land (800,000 hectares) remaining under fallow during the *Rabi* (dry) season. With current wheat production around quarter that of annual consumption (four million tonnes), increasing *Rabi* wheat production has potential to reduce dependency on foreign imports of grain. For this to happen however knowledge of the available land resource, how it is currently allocated and how much is available for wheat production is needed. With subsistence level agriculture practiced in southern Bangladesh this is a daunting task if using land based methods of assessment only. Access to satellite imagery linked with on-farm monitoring holds promise. Using satellite imagery as a tool for identifying changes in broad scale land use is well accepted however its use on small plot farming has in the past been limited by image resolution. Images from the Japanese Advanced Land Observing Satellite (ALOS) using the onboard Advanced Visible and Near Infrared Radiometer (AVNIR-2) provide observations at a 10 m spatial resolution over a 70 km swath width. Interpretation of these data suggests cropping management of small scale paddocks (<0.2 ha) can be captured remotely using sequenced images. Ground assessment at the paddock level validates use of this technology in identifying individual crops as well as the spatial distribution, area and availability of suitable land for future wheat production. This approach increases knowledge of the dynamics involved in small scale farming and provides spatial information to projects focusing on the expansion of cropping during the *Rabi* season in southern Bangladesh.

Keywords

ALOS; *Rabi* season; fallow; satellite imaging

Introduction

Agriculture remains a fundamental part of the Bangladesh economy with the majority of small holder farmers reliant on on-farm production to feed their families. Socio-economic and seasonal climatic conditions coupled with labour intensive technologies result in a variety of complex cropping systems. These systems contain a mix of sequential cropping, mixed-cropping, and relay cropping carried out on defined land units within the farm community. Farming in southern Bangladesh has traditionally depended on wet-season rice (*Aus & T.Aman*) with a third irrigated crop (*Boro*) grown in conjunction with cereal, vegetable and fodder crops during the *Rabi* (dry) season, Nov- Apr. Estimates suggest that 800,000 ha of agricultural land remains uncultivated in southern Bangladesh during the *Rabi* season due to limited irrigation resources or general unsuitability for cropping (Carberry, 2006). However, current wheat production is around one quarter that of annual consumption (four million tonnes) so increasing *Rabi* wheat production has potential to reduce dependency on foreign imports of grain.

Recent studies estimate a potential for one million tonnes per annum of new wheat production in southern Bangladesh with the introduction of heat tolerant varieties, improved agronomy and farmer education. A current ACIAR project in the region aims to improve the livelihoods of farmers in southern Bangladesh by introducing crops, such as wheat, onto currently fallow lands during the post-rice *Rabi* season. In achieving this outcome it will be crucial to delineate and characterise the areas where *Rabi* season cropping is feasible on currently fallow lands. Crop discrimination is a critical first step for most agricultural monitoring systems (Blaes, 2005). With subsistence level agriculture practiced in southern Bangladesh this is a daunting task if using land based methods of assessment only. Use of satellite imagery linked with on-farm monitoring may provide a cost effective solution for identifying and quantifying land remaining fallow during the *Rabi* season. Satellite imagery as a tool for identifying changes in broad scale land use is well accepted however its use on small plot farming has in the past been limited by image resolution. The ability to identify a particular crop makes it possible to estimate the area allocated to each crop type (Blaes, 2005). Research presented here evaluated use of satellite imagery to discriminate land remaining under fallow during the *Rabi* season and attempt to identify alternate land use classes (ie water storage, trees & current cropping areas).

Materials and methods

Case study site

The study site covers an area of 293ha surrounding the village of Hazirhat in the Noakhali district of SE Bangladesh (22? 46.10N, 91? 6.5E). This site contained paddocks sown to a wheat variety trial in the 2006-07 *Rabi* season and typifies current land use and farming systems practiced by small holder farms (typically ~0.2ha) in this region. The landscape mosaic of paddocks is interspersed with dense tree cover surrounding ponds and village structures.

Data

The Japanese Advanced Land Observing Satellite (ALOS), launched in 2006 was designed to provide high resolution observations for coverage, disaster monitoring and resource surveying. The three remote-sensing instruments carried on-board include 1) a **P**anchromatic **R**emote-sensing **I**nstrument for **S**tereo **M**apping (PRISM) providing high accuracy digital surfaces at 2.5m resolution (0.52-0.77?m), 2) the **P**hased **A**rray type **L**- band **S**ynthetic **A**perture **R**adar (PALSAR) a microwave sensor for day and night, cloud-free land observation with a resolution range of 7 to 88m (14 and 28 MHz) and 3) an **A**dvanced **V**isible and **N**ear **I**nfrared **R**adiometer type **2** (AVNIR-2) for spatial land use and classification mapping at 10m resolution. Data presented is based on AVNIR-2 images generated from 4 bands (red: 0.42-0.50?m, green: 0.52- 0.60?m, blue: 0.61-0.69?m and near infrared: 0.76 to 0.89?m) from the Noakhali region in SE Bangladesh during periods of zero cloud cover (Table 1).

Table 1. Scene identification for ALOS data for January and March 2007 observations.

Scene date	Scene ID	Centre Latitude	Centre Longitude	Scene area
16 Jan 2007	ALAV2A052093140	22.8944027 N	91.4008333 E	7173 km^2
3 Mar 2007	ALAV2A058803140	22.8945172 N	91.4134032 E	7171 km^2

Methodology

Identification of land class changes during the growing season is currently a major challenge. ENVI (ITT, Boulder, USA), image processing software designed for analysis of remotely sensed data was used in the processing and generation of images from the AVNIR-2 spectral data. To aid visual assessment a false colour image was first created (Figure 1) using three of the four measured wavelength bands (blue, near infrared and green). This allowed enhanced visual distinction between land class types (ponds; trees; fallow land; and cropping or pasture areas). This process was repeated for both the January and March data files and presented in Figures 1a and 1b.

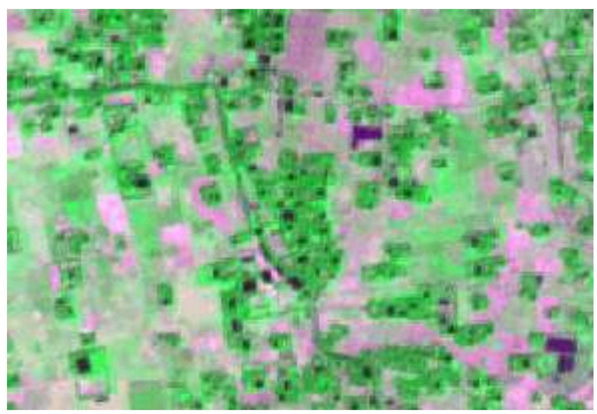
The image was subset to include the 293ha containing the Hazirhat site. This subset of the full image become the base image used in selection of four classes of land use: fallow, ponds, trees and other use (crops or pasture). The March image was then classified using a supervised classification (Maximum Likelihood) derived from the four classes to generate Figure 2a. This classified image was then overlayed on the original image in a number of configurations for clearly delineating land use classes or zones of interest. A contour overlay is presented in Figure 2b. Comparison of spatial or temporal change to classes across a number of images can easily be undertaken in the ENVI software.

Results and discussion

Land use patterns in the generated images using a supervised classification (Figure 2a) correlated well with visual assessment of the false colour images in Figure 1a and 1b. Images were assessed using local knowledge of ground conditions following the monsoon in November. Water bodies, storage ponds or irrigation zones were clearly depicted as were the areas under trees and fallow areas. Depth of colour adds a third dimensional aspect to the image with the change from white to dark purple indicating increasing levels of soil moisture or depth of surface water respectively (Figure 1). Darker green regions reflect increased levels of canopy cover (large trees) with lighter shades of green reflecting the current field crop or pasture. The fallow areas present strongly as white to light purple regions and represent newly cultivated or bare soil containing either no, very low or dead plant material. Statistical calculation of selected classes, based on Figure 2a, demonstrated strong separation between regions of fallow, ponds and trees indicating a strong correlation between zones selected to represent the classes and actual land use. Poor statistical separation between the trees and cropping areas suggest a more refined classification of tree canopy compared with field crops of lower canopy height is required.

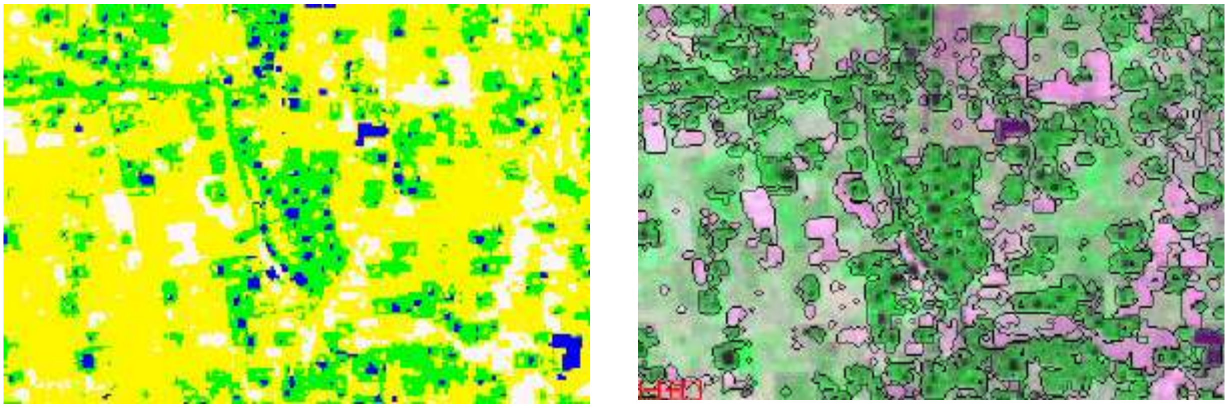
Area of each class type and their contribution to the case study site of 293ha are presented in Table 2. To validate this methodology, a wider region encompassing the study site of 1592ha is also included in Table 2 for comparison. Area under ponds (3.2%) or cropping (64.8%) remained relatively similar for the selected sample regions with a slight increase in fallow area (+2.9%) reflecting the heavily treed region within the smaller case study site. Land remains fallow during the *Rabi* for both social and economic reasons and is currently under assessment by this project. However, results suggest that if all 31.6ha of fallow in the study area of 293ha were sown to wheat producing 2.5 t/ha and wheat returned A$300 per tonne, then the gross return for this farming community would be in the order of A$23,700 (1.42 million Bangladesh Taka) less production costs. This figure has the potential to be much greater if all potentially available land is included.

a.



b.

Figure 1. Blended false colour AVNIR-2 images of the Hazirhat trial site, Noakhali showing change in land use from (a) January 16th, 2007 to (b) March 3rd, 2007. Darker purple regions represent higher water contents.



a. **b.**

Figure 2. (a) Image generated from supervised classification using four selected elements (fallow, trees, ponds and cropping) for March 3rd 2007. White regions represent land interpreted as remaining under fallow. Blue, green and yellow regions represent ponds, trees and cropping respectively. (b) March image containing a contour overlay based on classified zones. White to light purple regions represent land remaining fallow as of March 3rd, 2007.

Table 2. Comparison of area covered by each land use class based on 10m^2 pixels representing the case study site of 293 ha and a wider region of 1592 ha. Colour zones based on Figure 2a.

Land use class	Colour	Pixel number (in image)		Percent		Area (ha)	
		Study site	Wider region	Study site	Wider region	Study site	Wider region
1. Fallow	White	3167	21777	10.8	13.7	31.67	217.8
2. Trees	Green	6647	29179	22.6	18.3	66.47	291.8
3. Ponds	Blue	902	5125	3.1	3.2	9.02	51.3
4. Cropping	Yellow	18612	103120	63.5	64.8	186.12	1031.2
Total		29328	159201	100	100	293.28	1592.1

Conclusion

All countries need information to support decision making in activities aimed at socio-economic development (Hubert, 1998). As the demand for increased amounts and quality of information rises, and technology continues to improve, remote sensing will become increasingly critical in the future (Rogan and Chen, 2004). Having the ability to identify a particular crop makes it possible to estimate the area allocated to each crop type and thus compute relevant statistics (Blaes, 2005). The research presented aimed to develop a simple approach to identifying key land use classes given the operational constraints such as diversity of crop type, paddock size and location. At a pixel resolution of 10m, zones > 30m in width are required to overcome edge effects if a unique land use class is to be accurately identified. Paddock variability influences the spectral signal of each pixel with only a sharp delineation between values indicative of a major land use shift. Similar field crops in differing stages of growth will differ in their spectral response and may require further investigation using a series of images obtained during the crop growth cycle. However, interpretation of these data suggests useful landscape information at small scale paddock levels (<0.2ha) can be captured remotely using sequenced images. This study has demonstrated that ALOS time-series data can provide a practical solution for identifying and quantifying land use classes during the *Rabi* season. ENVI provides a powerful tool in enabling land classification and in quantifying the distribution and extent of those selected classes. This research aimed to identify and quantify the area of fallow land during the *Rabi* season, with generated images (Figure 2b) suggesting that this can be achieved cost-effectively.

However, areas indicated as fallow do not represent the true potential area available as land currently under pasture maybe suitable for cultivation and would add to the estimation of fallow area. Identifying pastoral lands as distinct from field crops is the next phase in providing a more accurate assessment of the extent of fallow land during this period. This methodology extends successfully to water bodies and dense tree cover but needs further ground monitoring if individual crops are to be identified. Future ground survey data used in the classification process will lead to improved accuracy in identifying the nature and physical extent of selected zones within a class. This approach increases knowledge of the dynamics involved in small scale farming and provides spatial information to projects focusing on the expansion of cropping during the *Rabi* season in southern Bangladesh.

References

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