

PADDY AREA ESTIMATION USING REMOTELY SENSED DATA TO SUPPORT CROP PRODUCTION FORECASTING

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ABSTRACT

Availability of reliable statistics on extents and expected productions under different crops in a season, well before the harvesting time, is a prerequisite for advance decision-making on agriculture imports. At present, they are estimated through enumeration of cultivated area under respective crops. This statistics is of little use for agricultural planning and decision making as they become available only after the cropping season is over. Geographic Information System (GIS) and Remote Sensing (RS) provide effective and efficient tool for crop monitoring and forecasting on real time basis. It also saves time and effort involved in collection of data. This study is aimed at evaluating the possibility of remotely sensed data to estimate paddy acreage as a component of crop production forecasting process. Combination of image processing and classification techniques such as supervised classification for green-red-infrared (1-2-3) bands, for Band 1-2-NDVI (Normalized Difference Vegetation Index) and for fused images, and NDVI density slicing was applied to estimate paddy extent in Wilgamuwa Divisional Secretariat. All classifications were performed using the same training sample. Accuracy assessment of all techniques was carried out using the same test sample. Percentage difference of paddy extent resulted from each classification method with respect to reported extent were 1.7%, 1%, 0.4% and 2.6% respectively for Band 1-2-NDVI supervised, Band 1-2-3- supervised, NDVI density slicing and supervised classification for fused images. Overall accuracy of each method was 95%, 93%, 90% and 89% respectively. This research has proved that remotely sensed data could be effectively used in forecasting and monitoring of paddy extents on real time basis with desired accuracy.

KEYWORDS: Paddy extent forecasting, Remote sensing, GIS, NDVI.

INTRODUCTION

Reliable management information on production estimates of agricultural crops in each cropping season is a prerequisite for policy decision-making on rice imports to Sri Lanka. Therefore, monitoring and forecasting of paddy production is a need and it is important as; (i) rice is the staple food of Sri Lanka, (ii) country's production accounts for 85% - 92% of the total requirement, (iii) the deficit is imported (Central Bank of Sri Lanka, 1999). The availability of reliable production estimates in advance with desired confidence limits would reduce the quantity of unnecessary paddy imports, save foreign exchange and thereby ensure sustenance of social and economic development of the country.

At present, the total paddy production in the island is estimated as a product of average yield and harvested extent (DOCS, 2001). The average yield is estimated through sample surveys. "Grama Niladari" and Agricultural Instructors estimate harvested extent through complete enumeration of paddy parcels. These estimates are of subjective nature since these are based on eye estimations and personnel judgments of officials (DOA, 1998). Moreover, the data are compiled much later than the end of crop season. Therefore, these statistics are of little use for agricultural planning and decision-making as they become available to the user only after (6-12 months) the cropping season.

Geographic Information Systems (GIS) and Remote Sensing (RS) provide effective and efficient tool for crop production forecasting on real time. Crop production forecasting using remotely sensed data involves two major components, namely acreage estimation and yield forecasting (Colwell, 1985). MacDonald and Hall, 1980 conducted Large Area Crop Inventory experiments and it was the first comprehensive study at regional/ country level wheat production forecasting using satellite data. Similar studies have since been carried out in many countries including Argentina (Redondo, *et al.*, 1985), Australia (Dawbin and Evans, 1988), Brazil (Moreira, *et al.*, 1986) and Sweden (Hall-Konyves, 1990).

A similar method could be applied to improve the paddy production forecasting in Sri Lanka. Therefore, a study was conducted with an overall objective of evaluating the possibility of remotely sensed data for estimating paddy extent as a component of crop production forecasting process in the island. The specific objective of the study was to evaluating the classification accuracy of four different approaches in the proposed method for estimation of extents of paddy.

MATERIALS AND METHODS

Indian Remote Sensing (IRS) multi-spectral and panchromatic satellite images were analysed in a GIS environment (ILWIS software) to estimate the paddy extent in Wilgamuwa Divisional Secretariat (DS) Division. Four types of image processing and classification techniques were used, (i). NDVI density slicing, (ii). supervised image classification for Green-Red-Infrared (1-2-3) bands, (iii). Green-Red (1-2) bands with NDVI supervised classification, and (iv) supervised classification for fused images (ITC, 2001a). Estimated paddy extent using remotely sensed data are compared with the statistics released by the Department of Census and Statistics. The methodological approach is summarized in figure 1.

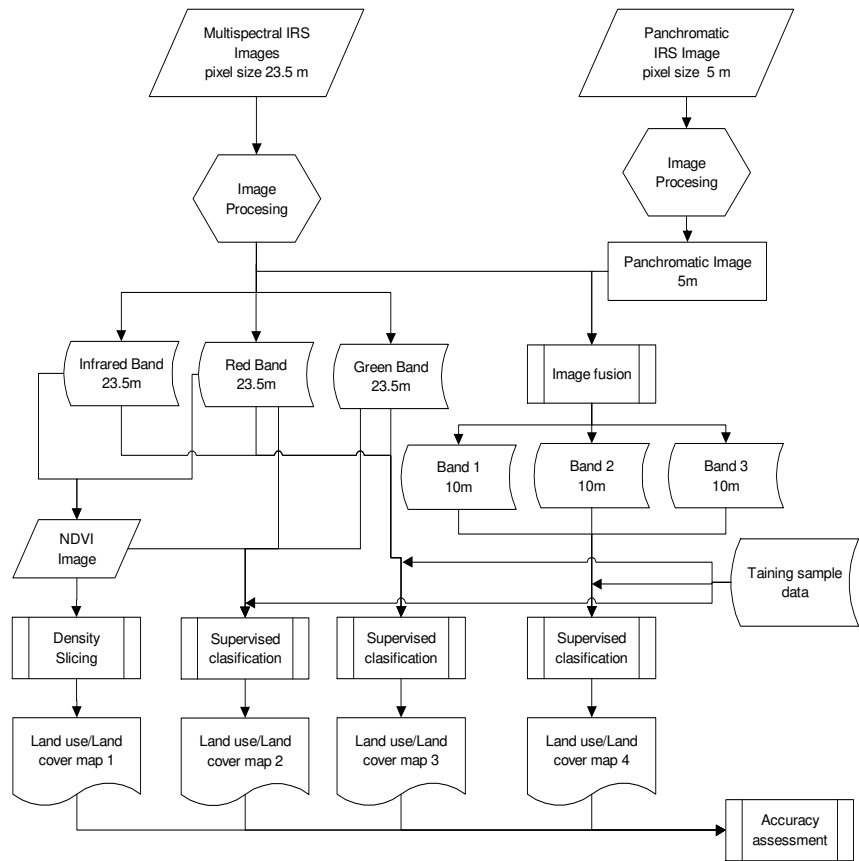


Figure 1. Methodology of the research.

Study Area

Wilgamuwa Divisional Secretariat (DS) division lies between 7°27'- 7° 43'N and 80°52'- 81°00'E located in the North-eastern side of the Central Province was selected for the study. The total area of this DS division is about 26000/ha. Most of the area is covered with Wilgamuwa wildlife-forest-reserve (northern part), paddy lands, open forest, grasslands, shrubs, and rock knobs. Paddy, which is the major agricultural crop in this area, is grown in both seasons, *maha* and *yala*. In *maha* season paddy cultivation is started around October and November. Harvesting time is in March. Several water bodies are scattered in the study area and the Mahaweli river flows along the eastern boundary. Northern part of the area belongs to DL₁ and the rest belongs to IL₂ agro-ecological zones and the major soil groups are Reddish Brown Earth

(RBE), Immature Brown Loam (IBL) and Low Humic Clay LHG (DOA, 1979).

Data

The multi spectral satellite data of 23.5m ground pixel size of IRS-IC LISS III and panchromatic (5m) satellite data acquired on 23rd March 1998 were used. Although these images were taken in late crop growth cycle, they were used in this study considering the reason of data availability and lack of funds for buying satellite images. However, crop area estimation can satisfactorily be forecasted if series of images throughout the year are available.

About 50% of the total area was surveyed for collecting training sample, which is used to run all image classifications, and test sample, which is used for accuracy assessments. About 950 data points, which were distributed equally among different land cover classes, were gathered during the field survey. Half of the data points were used as a training sample of all supervised classifications and the rest was used as a test sample of accuracy assessment.

Secondary data of paddy-cultivated extent in 1997/98 *maha* were taken from the agriculture statistics database compiled by the Department of Censes and Statistics to evaluate the classification results. Topographic sheets were used for image geo-referencing and basic data extraction.

Assessment of land use and land cover

Electromagnetic energy emitted by each ground pixel is recorded in multi spectral satellite images as digital numbers in different layers for different bands relevant to each region of the spectrum. Combinations of digital numbers pertaining to Green, Red and Infrared region of spectrum, compared with ground truth were the base of different land cover classification approaches. All the classification procedures were based on the same training sample data, which were, collected through field survey. Three types of classification approaches and an image density slicing approach applied on NDVI image were compared with each other and as well as with the available paddy statistics. The classification approaches applied in this study were;

- (1). Supervised classification for green-red-infrared (1-2-3) bands (Lillesand and Kiefer, 1994)

- (2). Supervised classification for fused images of multi-spectral and panchromatic bands. The method used for image fusion is Red-Green-Blue transformation into Intensity-Hue-Saturation (ITC, 2001b) and
- (3). Supervised classification for Green, Red (1-2) and NDVI images.

Maximum likelihood classification algorithm (Xiuwan and Heping, 1998) was applied in all supervised classification approaches. NDVI image was classified into land use/cover classes using image-slicing procedure by defining value ranges, considering NDVI values of each cover type of known ground pixels. (Shrestha and Zinck, 2001).

Accuracy assessment

In this study, accuracy assessment was carried out in ILWIS software for comparing the classification results with ground truth data (test sample). Confusion matrix and, percentage of overall, producer's and user's accuracy were derived to indicate the classification accuracy.

Crop cultivation statistics, which were compiled by the Department of Censes and Statistics, were used to assess the estimated total paddy extents. Spatial distribution of land cover was assessed by field observations and visual interpretation of IRS panchromatic (5m) satellite image.

RESULTS AND DISCUSSION

Although the satellite images were taken at the end of growing season where dry straw remains on most of paddy land during late March, the feature space (figure 2) for training samples shows considerable reflectance differences among different land covers. It allowed straightforward image classification for selected covers. The satellite images for early and mid growth stages of paddy that exhibits more uniform reflectance of paddy lands, will probably allow concise clustering and hence easier classification of paddy lands. Spatial distribution patterns of different land use / land cover types over the study area estimated by four different classification approaches are more or less similar (figure 3-6). Classification accuracy of each method is indicated by confusion matrix and, producer's, user's and overall accuracy (table 1 and 2).

Table 1. Confusion matrix of paddy for different approaches.

		<i>Referenced data</i>			
		<i>1-2-NDVI supervised Paddy</i>	<i>1-2-3 supervised Paddy</i>	<i>NDVI slicing Paddy</i>	<i>Fused Supervised Paddy</i>
<i>Classified Data</i>	<i>Forest</i>	0	2	1	0
	<i>Grass</i>	2	6	2	2
	<i>Paddy</i>	93	87	90	90
	<i>Rock knob</i>	0	0	2	3
	<i>Water</i>	0	0	0	0

Table 2. Producer's and User's accuracy for paddy of different approaches.

<i>Land use/cover classification approach</i>	<i>Overall classification accuracy</i>	<i>User's accuracy for paddy</i>	<i>Producer's accuracy for paddy</i>
<i>1-2-NDVI supervised</i>	95.0	96.8	94.7
<i>1-2-3- supervised</i>	93.3	93.9	97.9
<i>NDVI slicing</i>	89.8	86.5	94.7
<i>Fused supervised</i>	88.8	88.8	89.7

Percentage difference of paddy extent resulted from each classification method with respect to reported extent were 1.7%, 1%, 0.4% and 2.6% respectively for 1-2-NDVI supervised, 1-2-3- supervised, NDVI slicing and supervised classification for fused image methods (table 3). Overall accuracy of each method was 95%, 93%, 90% and 89% respectively. Fused image classification shows comparatively low overall accuracy. The reason behind it may be use of same training sample data for feature space clustering. Although the different overall accuracy values exist, estimated paddy extent is more or less same for all the approaches (table 3). Estimated paddy extent of four different approaches ranges from 3687-3825/ha. According to the statistics reported by Department of Censes and Statistics, cultivated paddy extent in 1997/98 *maha* season in Wilgamuwa DS division is 3728 ha. This paddy extent was 14.3% of the total area of the DS division.

According to the comparison of the percentage differences between estimated paddy extent and reported paddy extent, 1-2-3 classification and NDVI density slicing show more closer values to the reported extent.

Table 3. Estimated paddy extent compared with observed paddy extent.

<i>Method of estimation</i>	<i>Area (ha)</i>	<i>Difference with reported (%)</i>
<i>1-2-3 supervised</i>	3687	1.0
<i>Fused supervised</i>	3825	-2.6
<i>NDVI slicing</i>	3713	0.4
<i>1-2- NDVI supervised</i>	3795	-1.7
<i>Reported</i>	3728	0.0

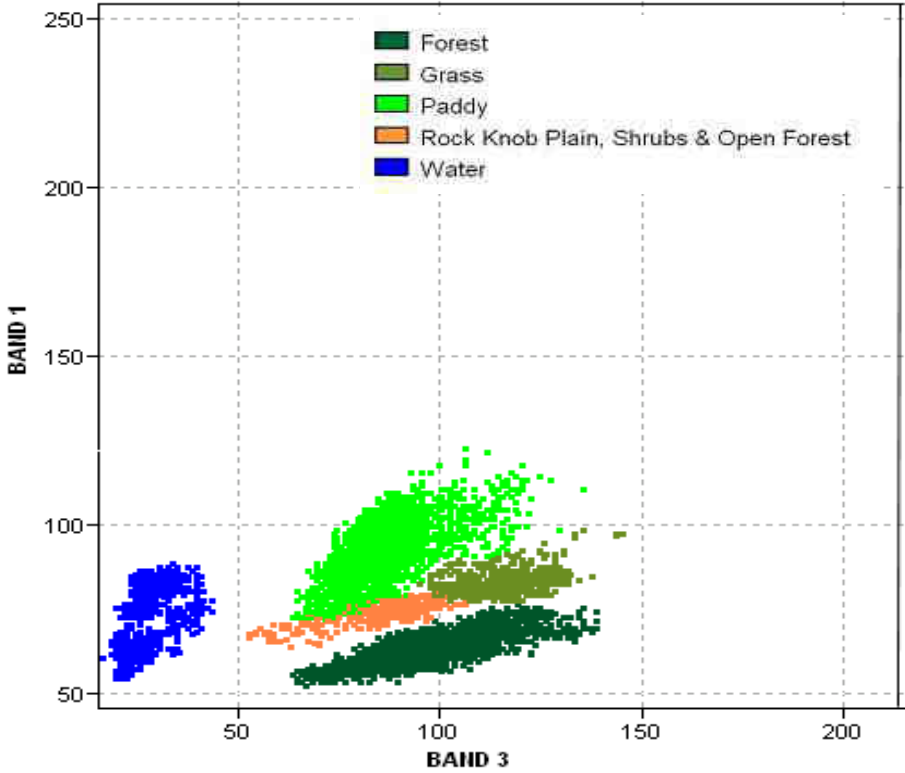


Figure 2. Feature space of selected training pixels for Band 1 and 3

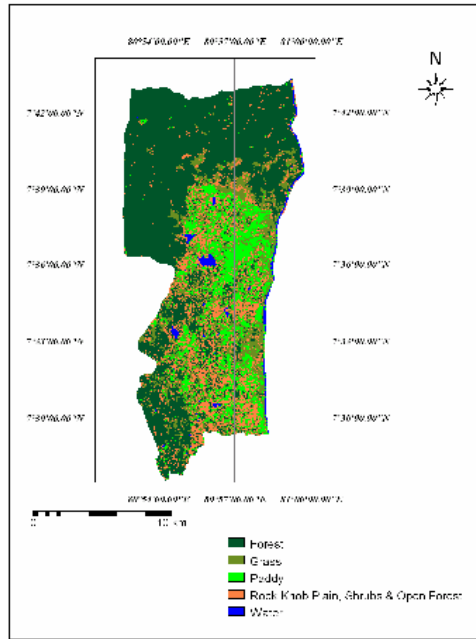


Figure 3: Resulted land use/ cover map of traditional Band-1-2-3 supervised classification approach

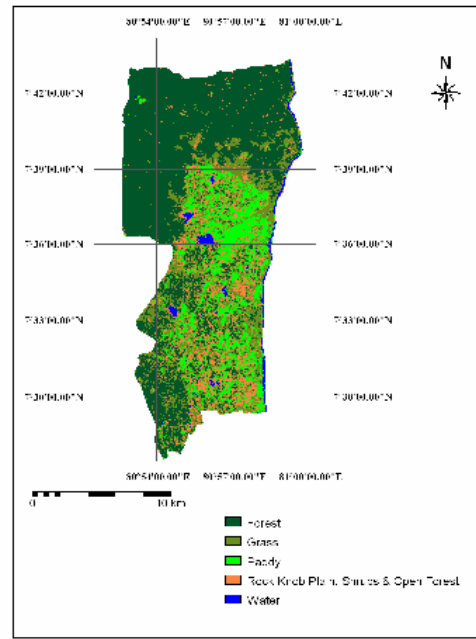


Figure 4: Resulted classified map of supervised classification approach using 3 bands after image fusion with 5...

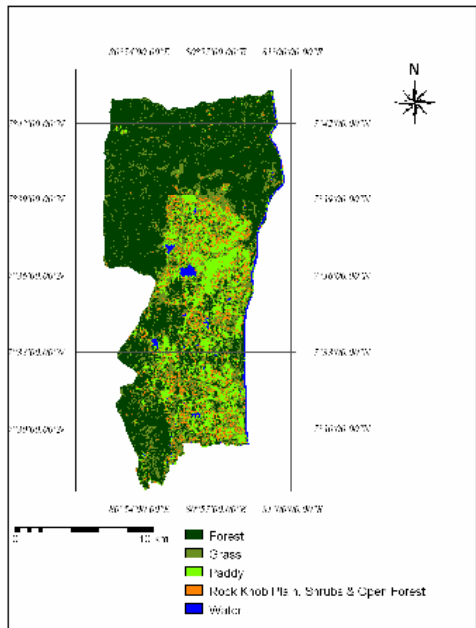


Figure 5: Land use/ cover map prepared by slicing NDVI image

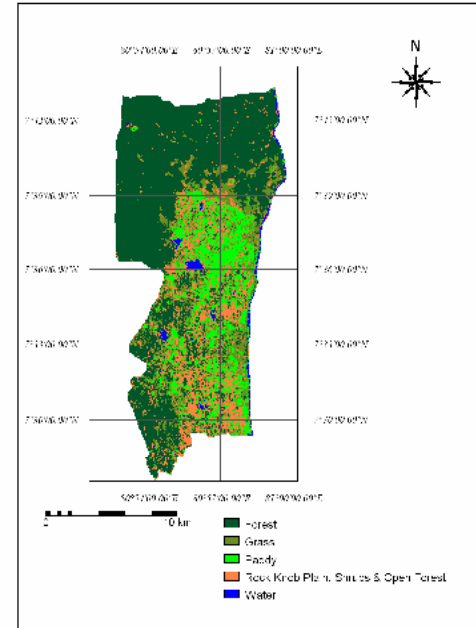


Figure 6: Resulted land use/ Cover map of Band-2-3-NDVI supervised classification approach

Apparently, the land use/land cover maps prepared by different approaches, show similar spatial distribution patterns (figure 3 –6).

CONCLUSION

This study shows promising result of using remotely sensed data for paddy area estimation on real time basis with desired accuracy for crop extent forecasting. Four types of approaches evaluated in this study are; (i). *Band-1-2-3* supervised classifications, (ii). Supervised classification for fused images, (iii). *Band 1-2-NDVI* supervised classification, and (iv). NDVI slicing. According to the results, all the four approaches can be applied for estimation of paddy area with more than 85% of classification accuracy. Except image fusion, only IRS multi-spectral images were used for all the other approaches and the results showed higher accuracy in all aspects. The result suggests that comparatively less expensive multi-spectral IRS image of 23.5m-pixel-size could be used to estimate the paddy extents and its spatial distribution in real time with desired accuracy.

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