SHORT NOTE

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PRODUCTION ESTIMATION OF HORTICULTURAL CROPS USING IRS-1D LISS-III DATA

P.P. NAGESWARA RAO*, H.M. RAVISHANKAR, UDAY RAJ AND K. NAGAJOTHI
Regional Remote Sensing Service Centre,
40th Main, Eswar Nagar, Banashankari, Bangalore-560 070, India
E-mail : pinnamaneni1953@yahoo.com

Horticulture crops including vegetables form an important component of food and a source of income to the farmers. These commodities undergo severe fluctuations both in production and consumption, thus facing unreliable price and market. Reliable and timely estimates of production of horticultural crops provide information in market planning and export. Satellite-based remote sensing (RS) has been one of the means for assessing the supply scenario. Efforts have been made to estimate the area and yield of major foodgrains like rice and wheat (Nageswara Rao and Rao, 1985; Patel *et al.*, 1991; SAC, 1995), mulberry (Nageswara Rao *et al.*, 1991), fruit crops like mango (Yadav *et al.*, 2002), vegetable crop like potato (Ray *et al.*, 2000) and commercial plantations like coffee (Nageswara Rao *et al.*, 2001) in India. These studies indicate that acreage and production estimation and location of the storage facilities for these crops are possible using RS and Geographic Information System (GIS) tools. While these studies are encouraging, there is a need for an in depth assessment of the capability of these tools in obtaining reliable estimates of production, monitoring of growth parameters and for obtaining in-season market intelligence on these crops. In the present study we have made an attempt to evaluate the use of Indian Remote Sensing Satellite (IRS) - 1D Linear Imaging Self-Scanning (LISS)-III sensor to estimate the production of fruit and vegetable crops grown and identify the likely date of harvesting of vegetable crops.

The study area covers 79,300 ha and bounded by longitudes 77°55' E to 78°20' E and latitudes 13°00' N to 13°20' N in the Kolar district of Karnataka state. Agriculture, horticulture and sericulture are the main rural occupations. Cereal crops dominate the landscape during kharif (June/July sowing) and horticultural crops during other seasons. In the command areas of large surface water bodies, paddy and many horticultural crops are grown in the spring season. Amongst the horticultural crops, potato and tomato are the major vegetables with potato as the dominant crop in rabi season (October/November sowing) and tomato cultivated round the year. Mango, banana, grapes etc. are the major fruit crops in addition to coconut and tamarind. Other vegetables and fruit crops are also cultivated in the taluk. Mulberry, eucalyptus

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and forest plantations occupy significant areas of the arable land.

IRS 1D LISS III sensor having four spectral bands (green, red, near infrared and short wave infrared) and a resolving power of 552 square metre size crop fields was used in the study. This sensor data acquired on six dates - November 1, 2001, February 5 and 28, March 13, April 19, and May 14, 2002 have been used for detailed analysis. Panchromatic (PAN) sensor data acquired on February 5, 2002 was also used for ground truth collection and for developing interpretation keys. Ground truth was collected during February, April and June 2002. Independent data collected by the personnel of Mother Dairy Foods Processing Ltd. (MDFPL) was used for accuracy verification of the remotely sensed estimates.

Analysis of change in the Normalized Difference Vegetation Index (NDVI) overtime (spectral - temporal profiles) of various crop cover types was carried out to select data sets that maximize classification accuracy (Ayyangar *et al.*, 1980; Badhwar *et al.*, 1987; Dubey *et al.*, 1991; Maxwell *et al.*, 2002). Supervised Maximum Likelihood Classifier (MLC) algorithm was used to classify LISS-III sensor data acquired in the beginning of the crop growing season (February 5 and 28, 2002). Crops planted later in the season were identified using a rule-based classification assuming that the crops planted early in the season will have higher NDVI than the late planted. Some additional information on the type of crop was obtained by visual interpretation of the texture from PAN sensor data acquired on February 05, 2002. Thus, a combination of digital analysis techniques, as suggested by Gordon *et al.* (1986), has been tried to obtain good accuracy of estimation of horticultural crops. At various stages of data analysis, digital masks of forest and water bodies have been used so that these cover types do not interfere with the delineation of horticultural crops. Production estimation was done by multiplying the remotely sensed area estimates with the average yield estimates reported by farmers and statistics of previous years.

Identification of likely harvest dates of vegetable crops was attempted by analyzing the time at which the crops reach their peak NDVI. For this purpose, reflectance (DN values) from red and near infrared channels of LISS-III data has been converted to radiance values with reference to pseudo-invariant features leading to generation of normalized NDVI. The NDVI values have been generated taking 5x5 pixels on different dates from corresponding cover types. It is assumed that the economically important components of the crops will be harvested 22 days after the crop attains its peak NDVI.

The separability of spectral classes was assessed using Bhattacharyya distance. This distance is calculated between each pairs of classes. A value of 2.0 suggests excellent, above 1.9 indicates good, and while below 1.7 is poor separation. The accuracy of classification was estimated based on confusion matrix between ground truth classes and analyzed (spectral) classes. In this case, the diagonal elements give the correctly identified class accuracy, while the values off the diagonal below a column heading indicate errors of commission and those along a row indicate errors of omission. Average, overall accuracy and Kappa analysis were carried out to get the best information from the error matrix (Congalton, 1991). The accuracy of area estimates was done based on an independent ground verification done by the officers of MDFPL and by calculating relative deviation (RD) with respect to the estimates reported by the Office of the Assistant Director of Agriculture (ADA), Kolar.

From the profiles of fruit and vegetable crops (Fig. 1) it is clear that the rice crop has highest peak followed by potato and mulberry crops. Each of them has reached a maximum NDVI at different times in the crop growing period when its profile does not overlap with others (crop window). Remotely sensing them during this period would result in better spectral separability than other periods. For example, early planted potato has maximum NDVI

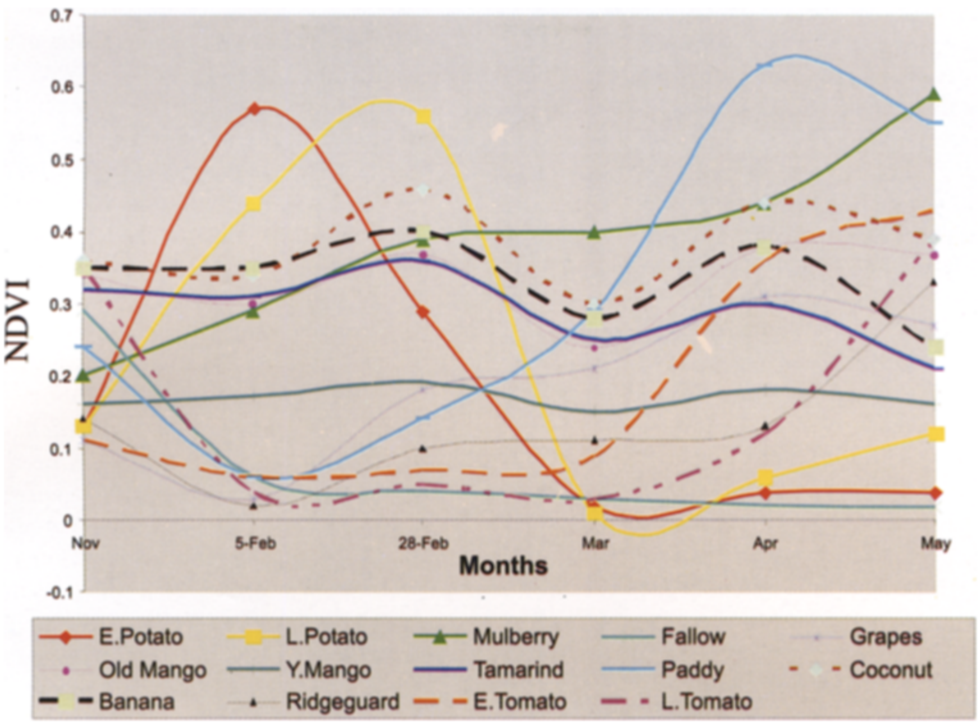

Fig. 1. Spectral-temporal profiles of vegetable and fruit crops and associated cover types. E and L stand for early and late planted crops, respectively.

in early February, late planted potato in mid February, rice crop in April and mulberry in May. Mulberry crop has another window during third week of March. Paddy crop can be distinguished from others during mid April and tomato sometime after May month:. Late planted tomato and ridge gourd among vegetables showed the low profile in the beginning but a rising trend later.

Analysis of NDVI profiles of fruit crops like banana, mango, coconut, tamarind, grapes, etc. showed no distinct crop window because these perennial plant crop cover types do not show any significant rhythm in their growth cycle. They remain green throughout, though subtle differences occur in their greenness. For example, banana and coconut have close greenness profiles till mid April and got separated by mid May. Similarly, old mango (planted more than 5 yrs) and tamarind have close profiles till mid March, separated out during mid April but got overlapped with Banana. Young mango (planted less than 5 yrs) has a relatively low profile throughout, indicating that the amount of green cover is less than exposed soil. Grapes did not have significant greenness in the beginning but subsequently it had greenness as good as young mango plantations by end February with some separability during March and April but overlapping with banana during mid May. The NDVI profiles thus provide clues on the growth pattern and phenology of crops that are indicative of the types of crops grown in the study area. It is found that the short duration vegetable crop covers types (e.g. potato) exhibit a spectral response very distinct from long duration fruit crops and thus enabling their identification.

Potato Production Estimation: Using February 05, 2002 data, 2317 ha of potato crop area was estimated. But during ground truth survey it was noticed that a significant area under late planted potato has not been accounted for. So, a second set of data acquired on February 28, 2002 was used and its total area was revised to 2654 ha (Table 1). Potato crop map of the study area supplied on 1:50,000 scale was verified on the ground by MDFPL personnel who reported that 90 per cent of fields were found to be correct. The estimated arrival of potato to the market was 36,613 tonnes by end March, 2002 and another 25,756 tonnes by end April, 2002, amounting to a total production of 62,369 tonnes. This information can be a very crucial input for determining, under GIS domain, the location of collection centres, cold-storage space required and transportable surplus from the study area.

Table 1: Comparison of Area Estimated by Remote Sensing (RS) and Office of the Assistant Director of Agriculture (ADA).

Crop/Cover type	RS (2002)	ADA (2002-03)	RD (%) = $\frac{(RS-ADA)}{RS} \times 100$
Potato	2654	3000*	(-) 13
Tomato	470	570	(-) 21
Mulberry	5135	5038	(+) 2
Total vegetables (Potato+ Tomato+others)	5500	5482	(+) 0.3
Paddy (Rice) crop	1501	1475	(+) 2
Banana	395	75	(+) 81
Mango	2420	2840	(-) 17
Coconut	1065	1846	(-) 73
Other crop land	41718	41469	(+) 0.6

* As reported by MDFP Ltd.

Tomato Production Estimation: The RS-based estimate of 470 ha as on May 14, 2004 is 21% less than the conventional estimate of 570 ha reported by the ADA. It appears that the tomato crop that reached maximum greenness after May 2002 would have gone undetected. About 23,692 tonnes of tomato was estimated to come to the market from the study area.

Area under other vegetables: Having found it difficult to estimate individual vegetables other than potato and tomato owing to their smaller areal extents, spectral confusions, sporadic distributions, etc. we resorted to area estimation under composite class 'vegetables'. The area under vegetables (other than potato and tomato) was estimated to be 1347 ha in February 2002 and 1375 ha in May 2004.

Coconut and Mango Area Estimation: The total area under coconut plantations has been found to be 1065 ha where as the ADA has reported 1846 ha. The under estimation could be due to those coconut planted in the border/fence, kitchen gardens or small plots with a few trees that cannot be detected using LISS-III data. Mango plantations were found to be at various growth stages, conditions, spacing and also with mixed crops. The area under mango plantations that are more than five year old could be estimated easily but not the younger mango plantations due to overlapping spectral signatures.

Paddy and Mulberry Area Estimation: Using April and May, 2002 data the summer paddy area was estimated to be 1501 ha and was found to be quite accurate. Mulberry has been found to be spectrally similar to many vegetable crops early in the season but showed some separability later on. Its area was analysed thrice (during February, April and May 2002) and estimated to be 5135 ha.

Identification of likely harvest dates: The date of harvest of potato was found to be about 22 days after reaching a maximum vegetation index of 0.5 to 0.6. In case of tomato, the harvesting starts around 15 days after reaching a vegetation index of 0.35 to 0.42; and after 35 days of reaching a vegetation index of 0.6 to 0.7 in case of rice crop. It is found difficult to identify likely harvest dates in case of perennial plantations like mango, grapes, etc.

User's accuracy of classification of horticultural crops shows that potato crop could be discriminated better in February than other dates; mulberry and older mango in April; coconut in February, fallow lands and wastelands in April and tomato and summer paddy in May. Overall accuracy (average of all classes) was found to be better in April than others. As expected the discrimination of ridge gourd, banana, grapes, young mango, tamarind and built-up area was not encouraging.

It was observed that each of the horticultural crop type has a time window during which its detection and accurate area estimation through remote sensing are easy. The NDVI profiles allowed us to assess the vigour, phenology, type and likely dates of harvest of the crops. We were able to estimate the area and production of crops like potato that are grown over large contiguous fields with an accuracy exceeding 90 percent. It was difficult to estimate the production of minor fruit and vegetable crops that are cultivated in field sizes that are smaller than the resolving power of the LISS-III sensor and having inadequate green cover at the time of data acquisition.

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