Single and Double Crop Maps of Indian Districts using MODIS 250-m Data

Sudhir Gupta, K.S.Rajan
Lab for Spatial Informatics, International Institute of Information Technology, Hyderabad
sudhir@research.iiit.ac.in, rajan@iiit.ac.in

Abstract

The report of the working group on agricultural statistics for the tenth five year plan set up by the Planning commission recognizes the critical role of space applications in improving crop statistics with the use of remote sensing technology. The group also states that the applications of remote sensing ushers the era of advanced IT(Information Technology) applications. In the context of crop forecasting, where the speed and accuracy of data flow and its inference is important, the advanced IT tools are essential. Policy decisions are influenced by statistical data and hence it is important that the data being used reflects the ground truth to the best extent. Ironically, we rely on agricultural census carried out with the year 2000-01 as the reference year as the eighth agricultural census with reference year 2005-06 is currently progressing in the country. With the aid of remote sensing, agricultural census can be carried out every year without human errors by devising fool proof algorithms. Such revised estimates of agricultural statistics will lead to more realistic policy decisions.

As a first step towards this objective, this paper explores the possibilities of using MODIS 250-m data to extract single and double cropping regions over some districts of Karnataka. The paper concludes by describing the challenges that are present in land use classification in Indian context. The paper also discusses the problems faced in validating land use classification results over large area with no good quality ground truth available at the required resolution.

1. Introduction

Data sets available from a variety of satellites have opened up tremendous possibilities for extracting a variety of features. Remote sensing can be a valuable tool for agricultural statistics that could save precious resources like time and money and provide real time information for farmers, policy makers, etc. The use of remote sensing data for estimating crop acreage estimation has reached a stage near operational level. Studies carried out for estimating acreage under different crops in many countries show a near 90 percent accuracy level. In many countries, production forecasting of certain crops, crop yield modeling and crop stress detection are done using remote sensing data [1]. To do so, the first step is to detect the cropping regions. Two broad approaches namely spectral and contextual image classification techniques are in vogue for classification of satellite images. Spectral techniques are based on the spectral response pattern of a pixel. These spectral bands are snapshots of the same area imaged at different wavelengths. The contextual classifiers consider the spatial context of the pixel in the image. But the dynamics of agriculture requires monitoring the area repetitively in a year in order to map the crop regions which call for a time series analysis of satellite images. This is made possible by the advent of moderate resolution satellite imagery with high revisit rates such as that of MODIS (Moderate resolution Imaging Spectroradiometer).

Vegetation indices computed from satellite images can give a good indication of the presence of vegetation in some cases. The time series of such vegetation indices observed over a period helps in further classification of the vegetation as crop and forest. Time series analysis of satellite data such as standardized principal component analysis [2] or Fourier analysis [3], are useful to obtain the information of seasonal vegetation changes characterized by phenology. Harmonic analysis has also been used to characterize seasonal changes for natural and agricultural land use/land cover [4]. A process called local maximum fitting has been devised in [5] to fit time series satellite data that can reduce the influences of noise such as cloud, haze and system noise. Further, they have taken forward this concept to fit AVHRR time series NDVI data to obtain the agricultural map of Asian region [6].

2. Data and Study Area

The MODIS 250-m Vegetation Index (VI) product (MOD13Q1), which consists of NDVI (Normalized Difference Vegetation Index) and EVI (Enhanced Vegetation Index) data composited at 16-day intervals, is used in this study. EVI was used as it is less noisy than NDVI. This data holds considerable promise for regional-scale crop mapping given its resolutions, large area coverage, and cost free status. Time series of EVI images for cropping seasons 2003-04. 2004-05 and 2005-06 were constructed for six districts of Karnataka state, India located in different agro climatic zones. These districts cover an area of 29,203 square kilometers

3. Methodology

3.1 Data filtering

Full potential of time series data is hampered by poor quality data caused by instrumentation problems, changes in sensor angle, atmospheric conditions (clouds and haze) and ground conditions. These problems tend to create data drop-outs (anomalously low parameter sensed) or data gaps. To fill these gaps and smoothen the data, we have used local maximum fitting (LMF) described in [5].The feature of the LMF processing is to be able to remove effects due to clouds, and to be able to capture the seasonal variation of the natural vegetation. The potential of LMF to aid classification is proved in [7]. Figure 1 shows the effect of local maximum fitting.

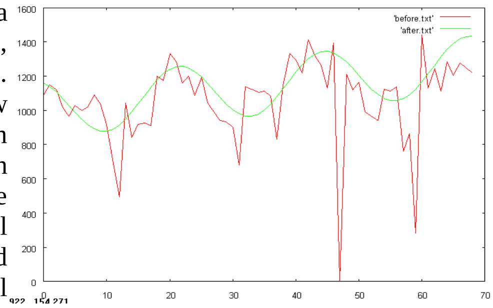

Figure 1: *Example of Local Maximum Fitting*

3.2 Land use Classification and validation

To overcome or reduce the manual inputs in the process of classification, a method has been developed for automatic extraction of the training samples that can be used for classification. This method also uses Constrained Derivative Dynamic Time Warping (DDTW) for time series pattern matching. This distance metric has inherent advantages for satellite image classification as land use practices such as field crops/vegetation exhibit temporal shifts from pixel to pixel based on the geographic location. Detailed discussion of these processes is not done in this paper.

Accuracy results are reported using several definitions of agreement between the map and primary or alternate reference land cover labels. Pixel-to-pixel comparison is the most restrictive protocol for defining agreement. It reflects a 'conservative bias' [8] due to the confounding of true classification error with errors attributable to misregistration or inability to confidently photo-interpret a sample unit. The second definition of agreement allows a match between the photo-interpreted label of a sample pixel and the most common class within a 3 by 3 pixel block centered on the sample pixel. This comparison takes into consideration that, for many applications, a certain level of spatial generalization from the original full resolution land cover data is appropriate. Yet another set of accuracy estimates are derived using a subset of the original samples, i.e., the sample pixel is located within a homogeneous area in which only one land cover type exists within the 3x3 pixel block. The estimates based on this comparison likely have an 'optimistic bias' [9] because of the restriction to areas where land cover is homogeneous and generally is easily identified. The latter method is used for validation of the land use map in this study as the reference map used has a resolution of 56-m.

3.3 Single/Double crop detection

The high level of noise present in MODIS data often makes it difficult to determine the number of annual seasons. For this reason, the local maximum fitted EVI data and not the raw EVI data was used for finding the number of seasons. A peak finder algorithm designed to reject small depressions as seasons reasonably finds the number of cropping seasons for a particular pixel. Green coloured curve represents raw EVI data and red coloured curve represents LMF fitted data in figure 2.

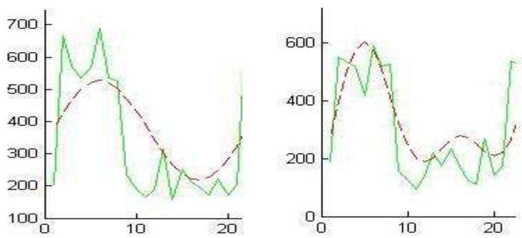

Figure 2: *Single and Double crop profiles*

4. Results

The single and double cropping areas for the six districts under study have been shown in figure 3. Yellow coloured regions refer to single crop areas and green coloured regions refer to double crop areas.

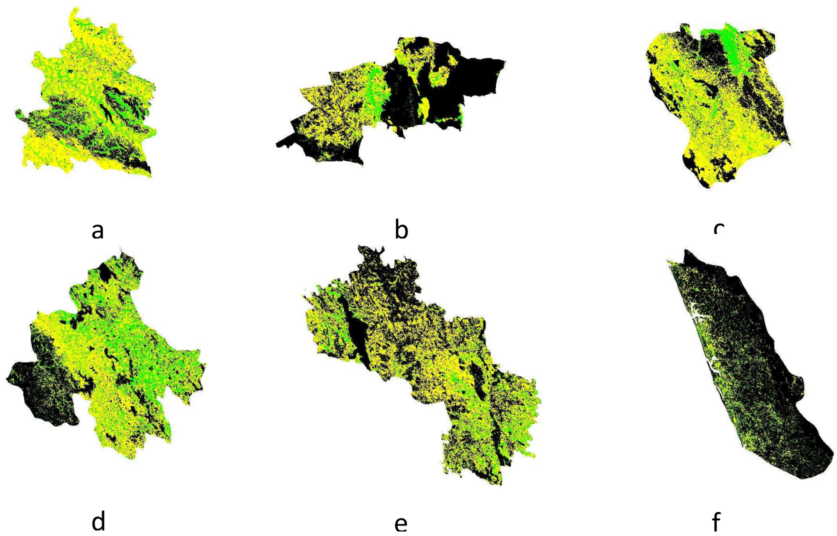

Figure 3: *a) Bidar District b) Chamarajnagar District c) Dharwad District d) Hassan District e) Kolar District f) Udupi District*

The average classification accuracy is of the order of 78%. Confusion matrices for individual districts have been computed and metrics like kappa co-efficient, user's accuracy, and producer's accuracy are derived from the confusion matrices. Single and double crop area statistics are computed but not evaluated due to lack of such data available at the district level for the required cropping year.

5. Conclusion

Thus remote sensing data can be successfully used to derive single and double crop regions at the district level for the whole nation. This study has not used any ancillary inputs which can improve the classification accuracy.

References

[1] H.P.Das,'Satellite based Agro advisory service', *Satellite Remote Sensing and GIS Applications in Agricultural Meteorology pp. 347-359*

[2] Eastman, J.R., and M.Fulk, 1993,'Long Sequence time series evaluation using standardized principal components', *Photogrammetric Engineering and remote sensing, 59(8), pp. 1307-1312*.

[3] Andres, L., W.A.Salas, and D.Skole, 1994,'Fourier Analysis of multi-temporal AVHRR data applied to land cover classification', *International Journal of Remote Sensing, 15(5), pp. 1115-1121*.

[4] Jakubauskas, M.E., D.R.Legales, and J.H.Kastens, 2001,'Harmonic analysis of time series AVHRR NDVI data', *Photogrammetric Engineering and Remote Sensing, 67(4), pp. 461-470.*

[5] Yoshito Sawada, Naoki Mitsuzuka, Haruo Sawada, 2005,' Development of a time-series model filter for high revisit satellite data', *Proceedings of the Second International Vegetation User Conference., pp. 83-89.*

[6] Izumi, N., Genya, S., Hitoshi, T., Sawada, H., 2002,'Agricultural Map of Asian Region Using time series AVHRR NDVI data', *Proceedings of Asian Conference on Remote Sensing.*

[7] Sudhir Gupta, Vinay Pandit, K.S. Rajan, 'Suitability mapping for locating a special economic zone', *Proceedings of Remote Sensing and Photogrammetry Society Conference (RSPSoc), United Kingdom, 2008.*

[8] Verbyla, D.L. and T.O. Hammond. 1995,'Conservative bias in classification accuracy assessment due to pixel-by-pixel of classified images with reference grids' *International Journal of Remote Sensing, 16: 581-587.*

[9] Hammond, T.O. and D.L. Verbyla. 1996,'Optimistic bias in classification accuracy assessment'. *International Journal of Remote Sensing, 17: 1261-1266.*