MAPPING SPATIAL VARIABILITY OF CROPPING PRACTICES USING TIME SERIES OF REMOTELY SENSED DATA

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ABSTRACT:

Understanding and interpreting the temporal variations of the vegetation growth can provide valuable information on its dynamics and in case of crops provide an estimate of the phenological milestones that can help describe the crop. The focus of this work is to use the phenological parameters derived from MODIS EVI time series composite data to map the variability in cropping practices. These maps christened as variability maps, map the cropping practices including the length of growing period (LGP) spatially over a given geographic region. The phenological parameters obtained were also analyzed to identify crop pixels which showed cropping in more than one season. This information was extrapolated to find areas under irrigation in the study area.

1. INTRODUCTION

Remote sensing can play a vital role in monitoring the fields and provide a snapshot of the outcome of the field practices which can then be processed to aid the agricultural scientist to make meaningful conclusions. Global coverage and repeated temporal sampling provided by satellites have significant potential for monitoring vegetation dynamics at regional to global scales. In many parts of India, multiple varieties-traditional, high yielding (HYV) and short high yielding (SHYV) varieties of crops are grown in the same region like, Annapoorna, IR-64, KMP-1 (Mandya-vani) (REF), based on weather and other local conditions including labour availability leading to different sowing/harvest dates. To effectively estimate crop production, it is required to estimate these cropping varieties and cropping practices. In addition, this lack of knowledge of cropping varieties and cropping practices across regions is a major deterrent in effectively understanding the response or modelling of these crops for climate and other input changes over time, thus limiting the adaptation potential of the region. In this paper, we have attempted to map the cropping practices of a particular geographic area using a time series of MODIS EVI. Cropping varieties can be estimated from cropping practices and hence it is imperative to identify the spatial variability of the cropping practices.

Crops or vegetation in general follow a systematic pattern of growth. Growth is a process and this process can provide valuable insights into the crop type/variety, cropping pattern, irrigation practices etc. Information about such a process cannot be deciphered from single date imagery. With the advent of moderate resolution earth observing satellites that have revisit time as small as one day, the growth process can be monitored at a much more finer temporal resolution. In the Indian context, studies have been carried out using high temporal resolution data for analyzing the trends in cropping practices of particular crops over particular geographic area. (Panigrahy et.al.,2005)

Our previous work demonstrated the utility of such a time series for extraction of phenological parameters which then helped in forming a season calendar for a particular geographic area (Gupta et.al.2008), This paper builds on that work to map the variability in cropping practices for a particular geographic area. The authors do not intend to interpret the patterns obtained, the reasons for such patterns and the implication as it is beyond the scope of this paper. The main objective of this work is to demonstrate that time series satellite imagery can aid the agricultural experts for better monitoring.

2. DATA AND STUDY AREA

The ideas developed in this paper have been tested on MODIS 250-m Vegetation index time series. Vegetation index product MOD13Q1 which consists of NDVI and EVI data composited at 16 day intervals is used in this study. Time series of EVI images for cropping season 2005-06 was constructed for Hassan, Dharwad, and Chamrajnagar districts of Karnataka State, India. The results reported in this paper are only for Hassan district.

2.1 Pre processing

One of the important steps in analysis of such time series information is to pre process the time series by filling data gaps and correcting data anomalies. Data gaps can occur due to sensor malfunctioning and data anomalies can occur due to dense clouds. A data anomaly is defined as sudden increase or decrease in the value whereas data gaps are formed due to missing values. The techniques of deriving EVI could also have led to data anomalies. Data anomalies and gaps can distort the analysis of time series and the resulting time series no longer reflects the ground process leading to wrong information being extracted from the data. Thus,

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algorithms for filling the data gaps and removing data anomalies are required. Such a pre processing step is also called as construction of time series and various methods have been proposed to construct the time series to match the ground process. (Colditz et.al.2008; Jonsson and Eklundh, 2002,2004). Popularly used techniques include minmax filtering/temporal window operation, savitzky golay filtering, fourier series fitting, gaussian model fitting and logistic function fitting. We have used local maximum fitting devised by Sawada et.al., (2005) which combines temporal window operation and fourier series fitting.
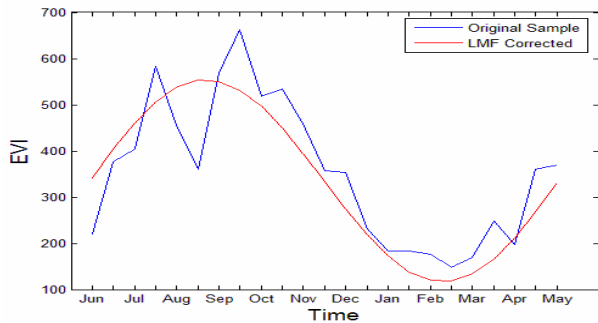

Figure 1. Effect of LMF Filtering

3. METHODS

The various steps involved in deriving the variability map and cropping season map are described in the flow diagram of figure 2. As explained in section 2.1, the time series of EVI is generated and the pre-processing steps are applied. The output of this step including raw and smoothed time series for all pixels is input to the time series classifier.

3.1 High level classification

This paper builds on the time series classification process developed by the authors the results of which are yet to be published. For the purpose of this paper, it will be assumed that crop pixels have been identified. Since, we are interested in the cropping practices, only crop pixel-time trajectories are subjected to further processing. The main function of this step is to eliminate non crop pixels.

3.2 Time series analysis

A number of methods have been developed to determine the start and end of growing seasons using time series of vegetation indices. These methods have employed a variety of different approaches including the use of specific NDVI thresholds (Lloyd, 1990; White et al., 1997), the largest NDVI increase (Kaduk & Heimann, 1996), backward-looking moving averages (Reed et al., 1994), or empirical equations (Moulin, et al., 1997). In our work, we have determined the inflection points of each crop pixel-time trajectory and determined the phenological parameters as defined by Jonnson and Eklundh. (2002,2004). The definitions of the phenological parameters extracted are 1) Time for the start of the season: datestamp at which there is a rise of 20% above the left minima. 2) Time for end of the season: datestamp at which the right edge is 20% above the measured right minima 3) Time for the mid of the season: computed as the mean value of the times for which,

respectively, the left edge has increased to its 80 % level and the right edge has decreased by 80 % level; and 4) Seasonal amplitude: difference between the maximal value and the base level. These parameters are illustrated in figure 3
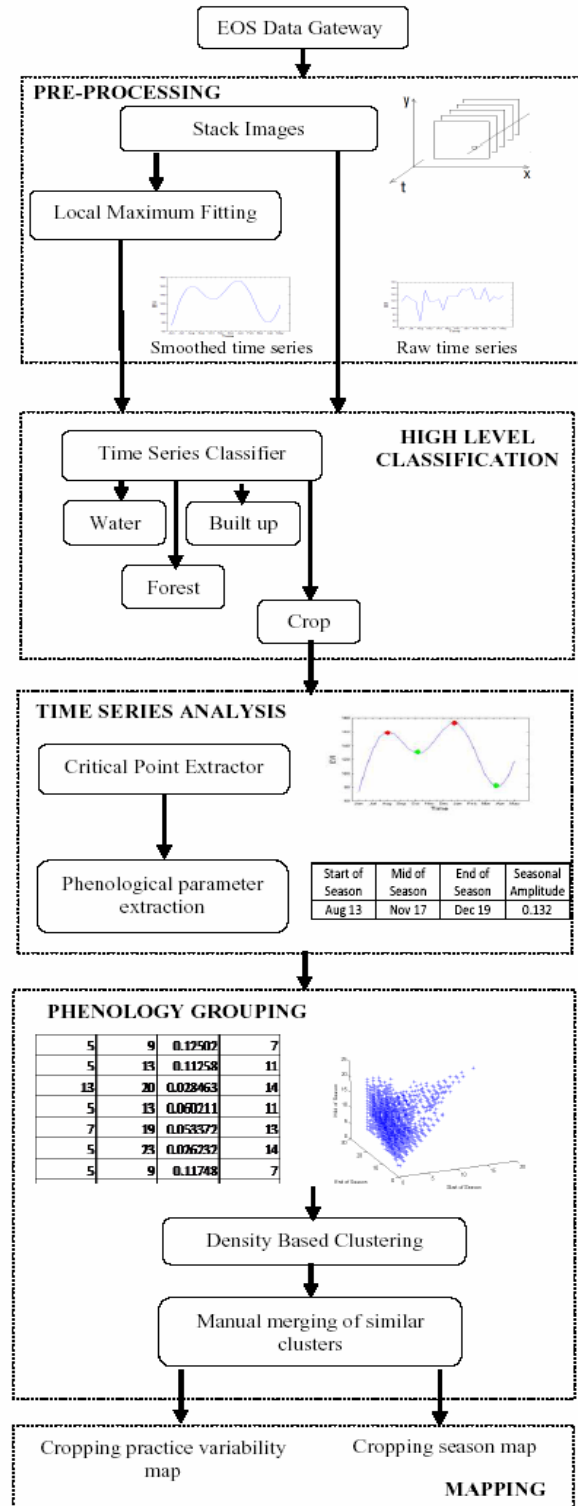

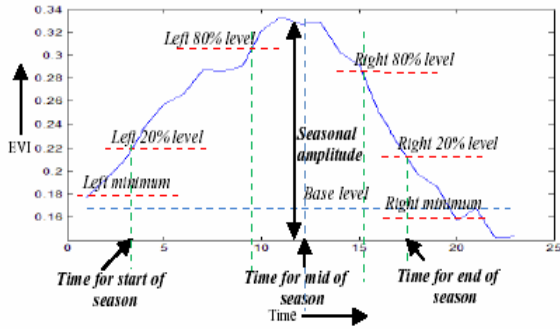Figure 2. Overall Flow Diagram of the Process

Figure 3. Illustration of Phenological Parameters Derivation

3.3 Phenology grouping

A density based clustering is done on the phenological parameters to group similar phenologies. Once the phenological parameters are obtained, they are clustered using a density based clustering method called Density Based Spatial Clustering of Applications with Noise (DBSCAN). Density based approaches apply a local cluster criterion. Clusters are regarded as regions in the data space in which the objects (phenology parameters) are dense. These regions may have an arbitrary shape and the points inside a region may be arbitrarily distributed. Since the phenologies are similar, the growth process is assumed to be similar and is hence clustered to form a single vegetation class (crop type). The clustering is manually improvised which results in clusters that differ considerably in the phenology parameters but also consist of sub clusters that differ marginally in the phenology parameters. These sub clusters are representative of the differing cropping practices in the region.

3.4 Mapping

The pixel locations of these sub clusters for each cluster are marked with different colors to map the variability in the cropping practices to produce the cropping practice variability map. The identified seasons were then classified as Kharif, Rabi and Zaid and as Annual crops manually. Pixel locations for the various combinations of Kharif, rabi and zaid were mapped spatially to produce the cropping season map.

4. RESULTS

The cropping practice variability maps derived are shown here. Each color represents a unique cropping practice. A sample set of the results are reported here, while the original result set has many more variations. The variations are in sowing, senescence or end of season dates/fortnights.
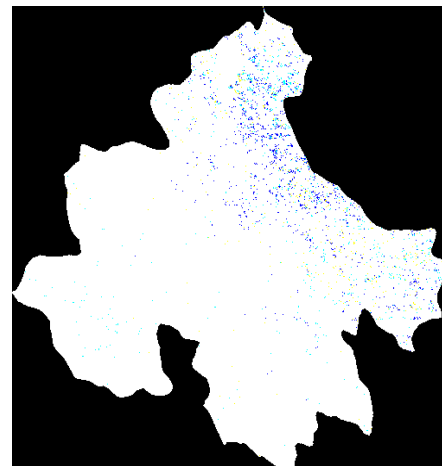
Figure 4 and 5 show the variability in the cropping practices of a Kharif crop which grows for around 150 days and 120 days respectively

Figure 6 and 7 show the pixel locations of the areas that grow crops in the Rabi and Zaid seasons respectively and the varialbility in their cropping practice.
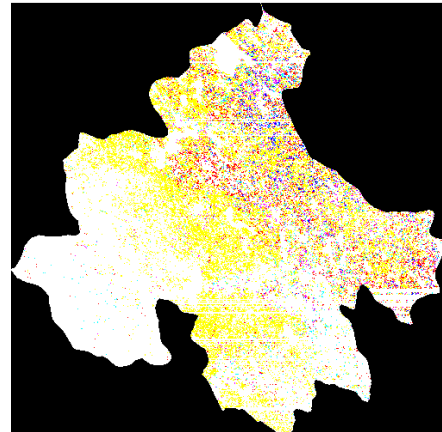
Season	Start	Mid	End
	10-Jun	3-Dec	9-May
	10-Jun	30-Sep	23-Apr
	10-Jun	17-Nov	7-Apr
	10-Jun	30-Sep	7-Apr
	10-Jun	1-Nov	7-Apr
	10-Jun	30-Sep	22-Mar
	10-Jun	17-Nov	22-Mar
	10-Jun	1-Nov	22-Mar
	10-Jun	30-Sep	6-Mar
	10-Jun	1-Nov	6-Mar
	10-Jun	17-Nov	6-Mar

Figure 4. Kharif Cropping Practice Variability Map For A 150 Day Crop

Season	Start	Mid	End
	28-Jul	30-Sep	7-Apr
	28-Jul	17-Nov	7-Apr
	28-Jul	1-Nov	7-Apr

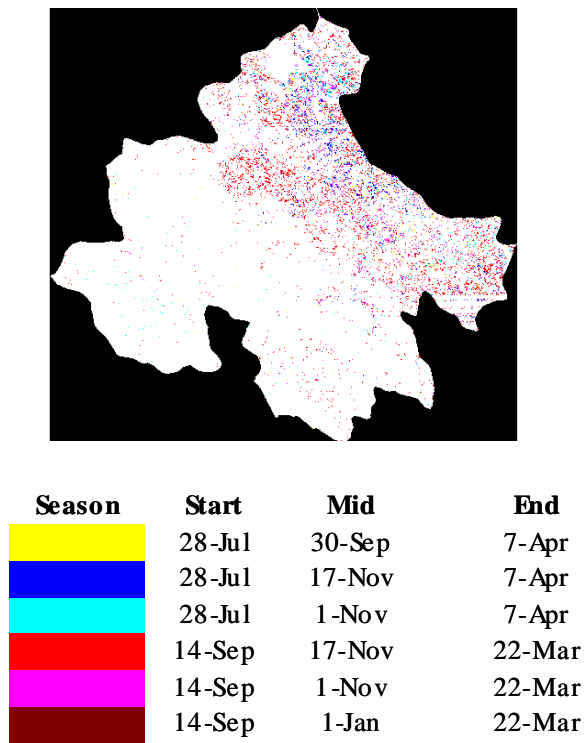Figure 5. Kharif Cropping Practice Variability Map for 120 day Crop.

Season	Start	Mid	End
(yellow)	28-Jul	30-Sep	7-Apr
(blue)	28-Jul	17-Nov	7-Apr
(cyan)	28-Jul	1-Nov	7-Apr
(red)	14-Sep	17-Nov	22-Mar
(magenta)	14-Sep	1-Nov	22-Mar
(dark red)	14-Sep	1-Jan	22-Mar

Figure 6. Rabi Cropping Practice Variability Map

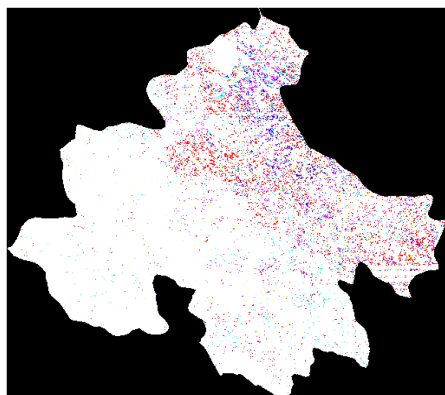| Season	Start	Mid	End
(yellow)	17-Jan	6-Mar	25-May
(blue)	17-Jan	7-Apr	25-May
(cyan)	2-Feb	7-Apr	25-May
(red)	19-Dec	2-Feb	7-Apr
(magenta)	19-Dec	18-Feb	7-Apr
(dark red)	2-Feb	22-Mar	9-May
(blue)	18-Feb	7-Apr	25-May
(teal)	17-Jan	6-Mar	23-Apr
(brown)	19-Dec	2-Feb	22-Mar

Figure 7. Zaid Cropping Practice Variability Map

The were plotted spatially. Such maps can be helpful in extrapolating other information like irrigated areas, etc
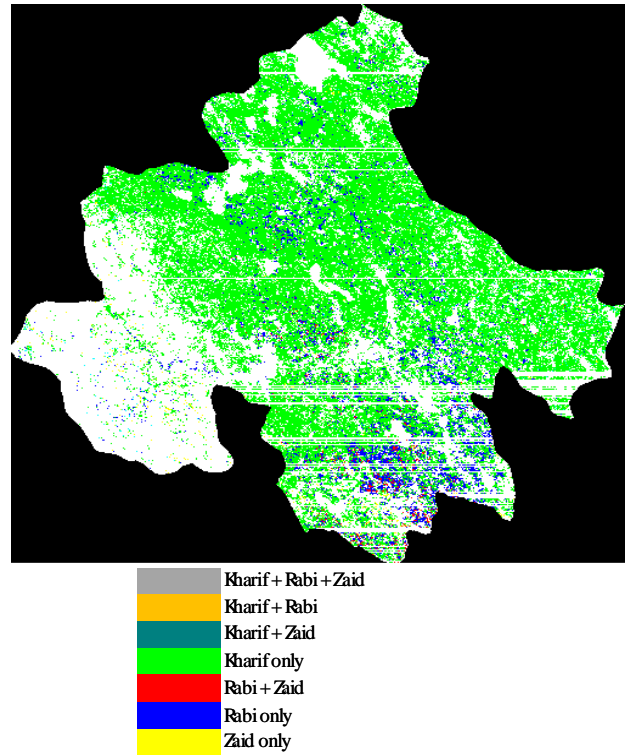

- Kharif + Rabi + Zaid
- Kharif + Rabi
- Kharif + Zaid
- Kharif only
- Rabi + Zaid
- Rabi only
- Zaid only

Figure 8. Cropping Season Map of Hassan District for 2005-06

5. DISCUSSION AND CONCLUSION

At regional and larger scales, variation in community, climate regime, soils, land management, progress of monsoon, distribution of seeds and fertilizers results in complex spatio temporal variation in phenology. The cropping practice variability maps are able to capture this variation which can then be analysed along with other spatial data that influence cropping practices by the agricultural expert to better understand the cropping practices. It was also found that there was a correlation between the direction of increasing sowing dates to the progress of the south west monsoon for all the districts under study.

The net sown area reported in statistics is 3,96,487 hectares while the net sown area estimated from our analysis of Kharif, rabi, zaid and annual crops from the cropping season map is 4,12,716 hectares which is an error of 4% and well within acceptable errors for such regional studies. The sown area during Kharif and Rabi was also compared with that available from statistics, the results of which are tabulated in table 1.

	Statistics	Our results
	hectares	hectares
Kharif	393481	367010
Rabi	66244	40756

Table 1: Comparison with Statistics

Since rabi and zaid crops can only grow in this district with irrigation support, it would be safe to conclude that areas which show cropping during non monsoon period are irrigated areas. However,such an assumption still needs to be evaluated.

An important observation that was made was the absence of triple cropping lands in this area. Pixel-time trajectories of pixels that showed the combination of rabi and zaid (Red pixels in figure 8) were being analyzed and we found that the phenological curve in the Kharif season had a very small length of growing period of around 30 days. Since, our algorithm was designed to discard such phenologies, they did not appear in the final list of phenologies. Whether this short length of senescence is because of data compositing process or indeed a ground process is yet to be known. Nevertheless, to achieve the best results and to investigate this discrepancy, we have to revert to the daily EVI data. Since, Kharif season is covered by clouds for majority of the time, optical sensors provide limited information that may not reflect the ground situation properly.

The spatial resolution of 250 meters provide by MODIS for such studies in Indian context can be very high owing to fragmented landholdings. Thus, the same study is expected to be done at a spatial resolution of 56 meters using AWiFS sensor on board Resourcesat-I, an Indian satellite.

In conclusion, this study has demonstrated the feasibility of using multi temporal remotely sensed data to describe vegetation dynamics, mapping phenological variation and understand the cropping practices over a given geographic area

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