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Extraction of agricultural phenological parameters of Sri Lanka using MODIS, NDVI time series data

W.G.N.N Jayawardhana[a]*, V.M.I Chathurange[b]

[a]*Space Application Division, Arthur C Clarke Institute for Modern Technologies, Katubedda, Moratuwa, 10400, Sri Lanka.*

[b]*Department of CPRSG, Faculty of Geomatics, Sabaragamuwa University of Sri Lanka, Belihuloya, 70140, Sri Lanka.*

Abstract

Management of crops is an essential part in the food production procedure. Having a thorough knowledge of growth stages of each crop is of paramount importance in this respect. Phenology (transplanting, panicle formation, flowering etc) is the study of cyclic and seasonal natural phenomena that are controlled by environmental and climatic factors. Monitoring the crop condition manually in the field is difficult and time consuming. Therefore recently, several methods have been introduced by using satellite derived vegetation indices. Extraction of phenological parameters is helpful for the purposes like irrigation management, nutrient management, health management, yield prediction and crop type mapping. Easily extracted parameters will be the important data base for agricultural researchers. This research is an attempt to extract paddy phenological parameters of Sri Lanka by using 16 years' (2000 to 2015) Time series MODIS Normalised Difference Vegetation Index (NDVI), which is highly sensitive for the green vegetation and the data were analysed using SPIRITS and TIMESAT software's. Periodicity converter in SPIRITS and Savitzky Golay filtering in TIMESAT and SPIRITS are helpful in smoothing the time series which are perturbed by noise due to missing values and Clouds. Phenology is considered as a sensitive climate change indicator but, it is very essential to have a comprehensive familiarity about the method of water supply that the study area is irrigated or rain fed so as to eliminate the wrong interpretation. As results, average of long time series of NDVI profile for a few agro ecological zones of Sri Lanka with extracted seven parameters (Start of the season, End of the season, Length of the season, Booting date, Base value, Maximum NDVI during the Season, Amplitude) and generated phenological parameter maps are presented here. The crop phenology is a very important element of agricultural monitoring, to ensure the security of the food crop production.

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* Corresponding author:*E-mail address:* nilushika.n.jayawardhana@gmail.com

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1. Introduction

The staple food of Sri Lankans is paddy. Growth and development of the plant involve continuous change. This means important growth events occur in the rice plant at all times. If the plant is unhealthy during any stage of growth the overall growth, development and grain yield of the plant are limited. It is important to have a comprehensive understanding of the growth and development of the plant[1]. Individual factors such as genes, age and rice variety and environmental factors such as weather and climatic conditions, water supply and diseases influence plants phenology (emergence, tillering, maturity etc)[2]. Understanding the phenology is very much essential for irrigation management, fertilization, and yield prediction. Crop distribution and acreage provide the basic information necessary for agricultural management and policy planning. In order to map crop areas, extracted phenological parameters are useful. Phenology is crucial for identification of factors influencing to crop stress, Monitoring farming activity, crop damage disaster monitoring, analysing seasonal ecosystem carbon dioxide (CO2) exchanges[3] and wide range of end users including, government, farmers, and researchers. Phenology is a cost efficient instrument for the early detection of changes in the climate[2].

The phenological stage of crop can be measured using field observation by the farmer, but it is difficult to maintaining the same method in large areas. Therefore, remotely sensed time series data are essential for the estimation of crop phenology stages across large areas and it's also cost effective. Historical crop calendars can be easily made and it may be an important database for food security information systems.
NDVI (Normalized Difference Vegetation Index) plays an important role in agriculture. Higher NDVI values usually represent greater vigor and photosynthetic capacity of vegetation canopy. Time series analysis of MODIS 250m surface reflectance 16 day composite data can be used to gain information on seasonal vegetation development. Here, the paddy phenological stages were detected. The main objectives of this study are extracting phonological parameters and preparing Seasonality Parameter maps for different agro ecological zones in Sri Lanka. To fulfill the agriculture application requirement, researchers are encouraging to make benefit from time-series remote sensing data[4].

2. Methodology

In Sri Lanka there are mainly two cultivated seasons namely yala and Maha. Yala Season is effective during the months of April to September whereas Maha Season is effective from October to March in the next year. MODIS Vegetation Indices 16-Day L3 Global 250m (MOD13Q1) is the basis of study, for the period 2000 to 2015/July. Two tiles which covered the Sri Lanka are h25v08 and h26v08. MOD13Q1 has different spectral bands including, NDVI, EVI (Enhanced Vegetation Index), Red, NIR, Blue and MIR .For this study NDVI layer is used which is a normalized reflectance difference between the near infrared (NIR) and visible red bands. The downloaded MOD13Q1 data are in HDF-EOS data format, and sinusoidal projection. Firstly the downloaded MODIS tiles which cover the Sri Lanka are mosaicked and reprojected using MODIS Reprojection Tool (MRT).MRT is freely available software Tool for all registered users. Here used the periodicity converter of SPIRITS (Software for the Processing and Interpretation of Remotely sensed Image Time Series) software to construct decadal time series using existing 16 days series. SPIRITS is the windows based software aiming at the analysis of remotely sensed earth observation data[5].
In order to extract phonological parameters (Figure 1) Pixel wise NDVI time series were generated from 2000 to 2015/July, using TIMESAT Program. TIMESAT is primarily designed to process time series of vegetation index derived from satellite spectral measurements[6] .To derive the NDVI Profile the averaged pixel values for each agro ecological zones are used. Long Time series were made as an input of TIMESAT Program. TIMESAT implements three processing methods based on least squares fits to the upper envelope of the vegetation index data. The first

method uses local polynomial functions in the fitting, and the method can be classified as an adaptive Savitzky-Golay filter. The other two methods are least-squares methods, where data are fitted to non-linear model functions of different complexities. All three processing methods use a preliminary definition of the seasonality (unimodal or bi-modal) along with approximate timings of the growing seasons[2]. The accuracy of fitted NDVI profile as well as the extracted phonological parameters is highly dependent on the selected time series filtering parameters. Selecting optimal settings parameter is an act of trial and error and needs long term testing. The parameters used for this study is included in table .

Table 1. TIMESAT Settings for NDVI time series

parameter	Value
Spike method	Median filter -2
No of envelop iterations	3
Adaption Strength	5
Savitsky-Golay window size	7
Start of the Season method	Amplitude
Season start, Season stop	0.1

The following six Seasonality parameters were calculated.

a. Time for the Start of the Season – Green up date
b. Time for the end of the Season – Harvesting date
c. Length of the Season – Length of growth duration
d. Base level – Average of the left and right minimum values
e. Time for the mid of the Season – Booting stage
f. Largest data value for the fitted function during the season – Maximum NDVI value
g. Seasonal amplitude – Difference between maximum NDVI value and the base level.

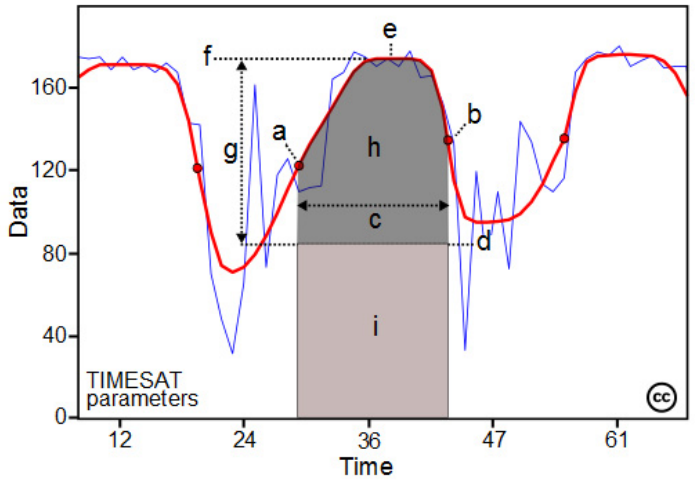


Figure 1. Phenological Parameters Illustration (a to g) [6]

3. Results and Discussion

The most of the Satellite images have the problem of cloud cover. MOD13Q1 is the Satellite data product and it is the Maximum Value composite of 16 day therefore cloud pixels are replaced by maximum value of the corresponding 16 days of period but all of the cloud pixels in the imagery are not removed. Still there are noises especially due to cloud contamination over Sri Lanka. Starting the processing with cloud pixels causes to wrong interpretation. Here Time

series filtering with TIMESAT are helpful to remove cloud pixels considering the time series data. It was extremely better than spatial filtering. (Figure 2)

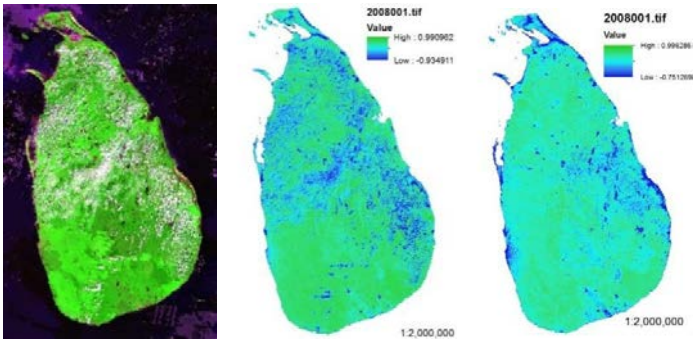


Figure 2. (a) Original Image, Cloud Contamination Over Sri Lanka on 1st January 2008 (b) NDVI before time series filtering, (c) NDVI after time series filtering

The periodicity converter of SPIRITS software interpolates decadal time series. When converting the periodicity, the tool automatically applies the smoothing technique, therefore the decadal series is almost better than 16 day original MODIS series. This series was used as an input for TIMESAT Program. Then the remaining noises are compensated by Savitzky Golay Algorithm. The long time series average values of selected pixels of selected agro ecological regions are used to derive seasonality data. Taking the average values of agro ecological zones NDVI profiles seems to be better because an agro-ecological region represents a particular combination of the natural characteristics of climate, soil and relief. When an agro climatic map, which can be considered as areas where the integrated effect of climate is uniform throughout the area for crop production. Most of the noises are trends to low NDVI values. Therefore the adaptation was used to the upper envelop function of TIMESAT to keep the higher NDVI values (Figure 3). Many time series are remaining positive and the negative outliers seriously make an impact on the function fits, here the output series is in a good quality without abnormal spikes and it makes the determination of Seasonality variables easy.

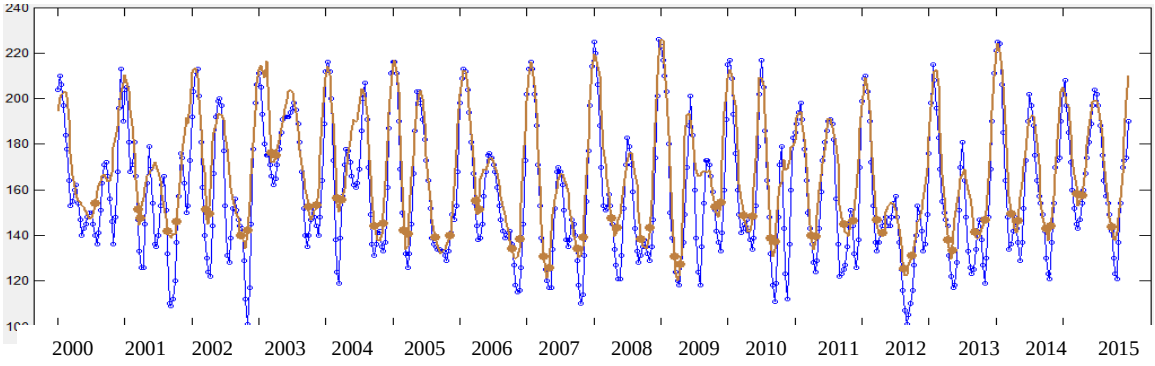


Figure 3. Smoothed Time series of the years 2000 to 2015/Jun/31 (before 2000/Feb/18 and after 2015/Jun/31 are false values) of Kurunegala District IL3 Agro ecological zone, Blue line indicates the decadal NDVI data. Brown line indicates the smoothed time series fitted data. Brown dots display the start and end of the season time

Analyzing these historical series can detect the changes of the phonological event, it can be seen that in some seasons are not cultivated during the year, and sometimes it may be owing to the results of natural disasters like flood or

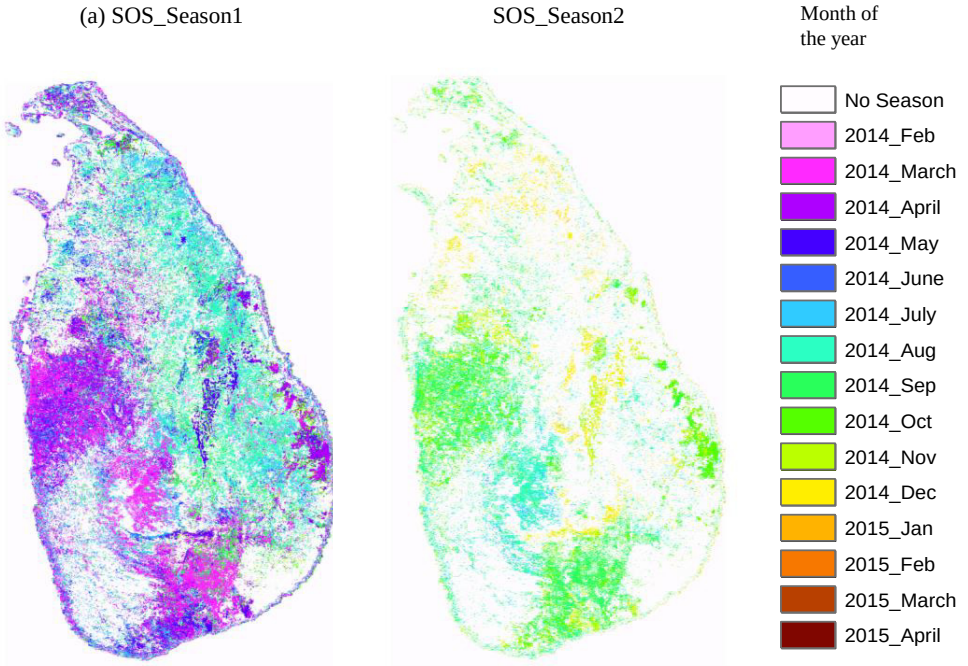
drought, or any plant disease. In order to detect the exact reason whether it is caused by climate change or not, it needs more data sources like accurate land cover map which differentiates irrigated and rain fed areas, rainfall data, soil characteristics information and extensive idea about the crop planting habitat of the study area.

The extracted phonological parameters for the paddy areas of DL2b, DL1b, IL3 and DL1c agro ecological regions are listed in the table 2. Those dates are matched with the defined Yala and Maha Seasons.

District	Agro Ecological Zone	Season	SOS (Green up Date)	Booting Date (Max NDVI date)	EOS (harvesting Date)	LOS (in days)	Base Value (NDVI)	Peak value (Max NDVI)	Amplitude (NDVI)
Ampara	DL2b	2014_yala	2014/April/01	2014/Jun/01	2014/Sep/01	146	14.56	157.9	59.28
		2014_maha	2014/Oct/21	2014/Dec/21	2015/Mar/01	130	13.08	202.1	94.94
Anuradhapura	DL1b	2014_yala	2014/May/11	2014/Jul/11	2014/Oct/01	133	156.2	174.2	17.95
		2014_maha	2014/Nov/01	2015/Jan/11	2015/Mar/21	144	156.2	197.3	41.14
kurunegala	IL3	2014_yala	2014/May/01	2014/Jul/11	2014/Oct/01	148	139.3	192.5	53.12
		2014_maha	2014/Oct/21	2015/Jan/01	2015/Mar/11	140	145.3	205	59.79
Polonnaruwa	DL1c	2014_yala	2014/April/01	214/Jun/21	2014/Aug/21	127	145.3	206.1	60.77
		2014_maha	2014/Nov/01	2015/Jan/21	2015/Mar/21	138	137.5	211.9	74.35

Table 2. Extracted Phenological Parameters from TIMESAT Program (SOS- Start of the Season, EOS-End of Season, LOS-Length of Season)

Mapping of extracted Seasonality information of each pixel is very important and it gives the broad idea in one perspective view (Figure 4).



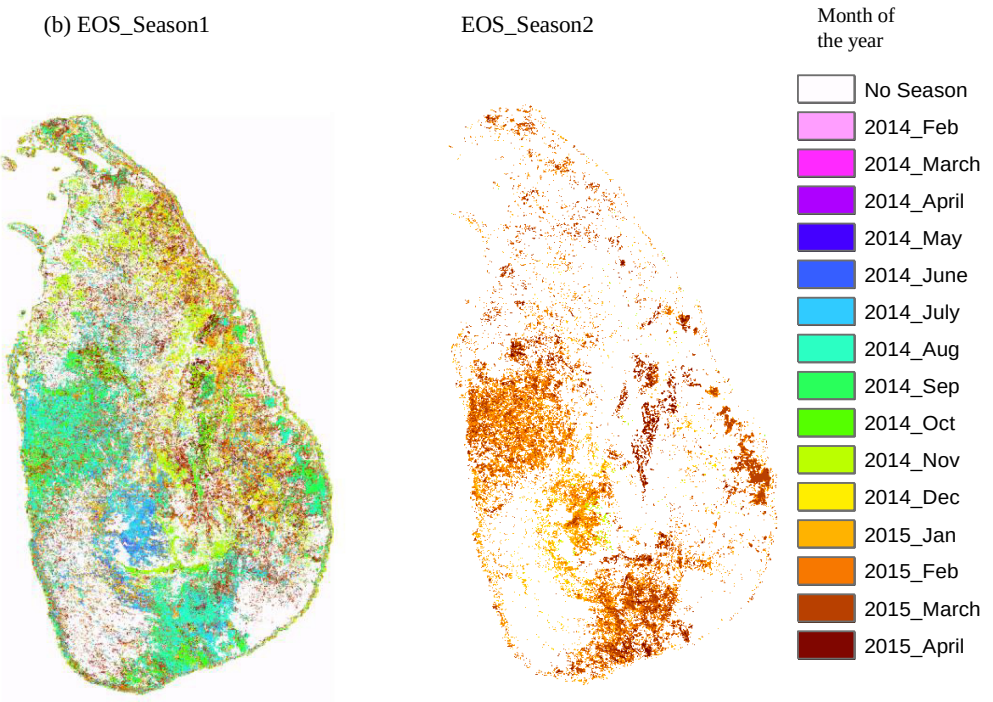


Figure 4. Seasonality maps for the detected two seasons from 2014/Feb to 2015/April, (a) Start of the Season, (b) End of the Season

4. Conclusion

This research is an attempt to show, the feasibility of use time series of satellite derived vegetation Indices to crop monitoring and other agricultural operations in Sri Lanka. In this paper we presented the Satellite data, preprocessing methods and software's to produce a pixel based daily time series, detect phenology parameters and Mapping crop phenology parameters. It needs high temporal resolution vegetation index time-series. MODIS 16 day composite is too much large temporal resolution for extract time sensitive factor like phenology, therefore Interpolation of daily time series is vital. When performing the TIMESAT Savitzky Golay filtering the quality of the output time series is highly depend on the selection of the TIMESAT settings, it is depended on users' satisfactory about the quality of the fitted result. TIMESAT is advance in algorithms and user friendly software to detect crop phenology and map them. Furthermore cloud free images are derived as the byproduct of phenological parameter extraction methodology in TIMESAT is fine source for other agricultural studies.

Different crop types have different time ranges in growth stages that can be used as a variable to classify the crop types and mapping cultivated areas. Created seasonal variable maps of whole country are given the broad picture for the agricultural research. The higher consideration is needed when use phenology to predict climate and better to have good understanding of the study area, whether irrigated or rain fed. If real time data can be used, it will be supportive to efficient crop monitoring and management in large agricultural areas.

References

1.Saichuk J. Louisiana Rice Production Handbook, Chapter 4, Rice Growth and Development, 1987:41-43

2. Koch E, Bruns E, Chmielewski F, Defila C, Lipa W.and Menzel A, Guidelines For Plant Phenological Observations, 2007
3. You X, Meng J, Zhang M, and Dong T, Remote Sensing Based Detection of Crop Phenology for Agricultural Zones in China Using a New Threshold Method , Remote Sens. 2013, **5**, 3190-3211; doi:10.3390/rs5073190
4. Zhuokun Pana, Jingfeng Huanga, Qingbo Zhou, Limin Wang, Yongxiang Chenga,Hankui Zhange, George Alan Blackburn, Jing Yang, Jianhong LiuhaInstitute, Mapping crop phenology using NDVI time-series derived from HJ-1A/B data, 0303-2434/© 2014
5. Eerens H. and Haesen D, Software for the Processing and Interpretation of Remotely sensed Image Time Series User's Manual- version 1.3-2015
6. Lars Eklundh and Per Jönsson, TIMESAT a program for analyzing time-series of satellite sensor data, Computers & Geosciences 30. 2004: 833–845