THE FILTERING OF SATELLITE IMAGERY APPLICATION USING METEOROLOGICAL DATA AIMING TO THE MEASURING, REPORTING AND VERIFICATION (MRV) FOR REDD

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ABSTRACT: Since Reducing emissions from deforestation and degradation in developing countries (REDD) scheme has been manifested at the thirteenth Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2007, varied approaches of measuring, reporting and verification (MRV) carbon emissions from forest were generated. The suitability of different methods depend on many factors, like cost, accuracy, technologies, scale (sub-national to international level) and availability of data. Among those approaches the application of remote sensing technologies are likely to play leading role. Satellite images require involvement of data analysis. This study emphasizes the use of filtering for satellite images to overcome serious obstructions which degrade their qualifications, for instance, cloud and haze. Improved Local Maximum Fitting (LMF) algorithm was applied. Firstly, 'Min Max Filter' using meteorological data was introduced. In order to obtain the reliable NDVI value, acquired raw data (in this study, 8-days MODIS images of Suphanburi province in Thailand) should be selected meticulously before going on the further step of fitting model. The filtering methods are divided to 2 concepts, changing window size depends on the average monthly rainfall historical statistical data and the number of continuous cloud-days using cloud mask method. The advantages are to avoid the case that correct NDVI value may be eliminated by using too large window filter, or the noise cannot be eliminated by using too small window filter. Then, the filtered images were used to the next step of the time series fitting model with Fourier formula. As the result, the Improved Local Maximum Fitting can eliminate the influence of cloud and haze and increase qualities of original satellite images which can contribute to identify type of forests and to monitor forest condition, furthermore utilization for leakage monitoring.

1. INTRODUCTION

1.1 Background

Global warming, the world's attentive environmental problem caused by anthropogenic greenhouse gas (GHG) emissions has considerably been in urgent need of solving. Fossil fuel burning for producing electricity in industrial countries has directly increased about three-quarters of the total global emission of greenhouse gases annually. The remaining one-quarter increase is indirectly caused by deforestation and degradation, particularly in developing countries. Meanwhile, the problem continues into the crisis, considerable solutions of how to deal with large cuts in emissions within a short time at a low cost are required.

Reducing emissions from deforestation and degradation in developing countries (REDD) is one of concepts responding to GHG mitigation requirement. REDD scheme has been manifested at the thirteenth Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) in 2007. In present, REDD additionally includes forest enhancement, sustainable management of forests and forest conservation is referred to as REDD+. The strategy to achieve a target reduction of GHG emission is based on an understandable idea as industrial countries pay for carbon credit to developing countries to reduce emissions from forest.

This idea seems easily feasible. Practically, to establish measuring, reporting and verification (MRV) carbon emissions from forest for REDD face complexity. How reduction in emissions can be measured properly? Accordingly, official MRV guidelines were, up to now, developed by the Intergovernmental Panel on Climate Change (IPCC). The latest IPCC2006 Guidelines for National Greenhouse Gas Inventories for Agriculture, Forestry and Other Land Use (GL-AFOLU) represent the most updated source of methodological information. Along with the ad hoc REDD working group called the Global Observation of Forest and Land Cover Dynamic (GOFC-GOLD) developed a sourcebook of methods and procedures for monitoring and reporting GHG emissions. Since then, varied approaches of MRV were generated. The suitability of different methods depend on many factors, like cost, accuracy, technologies, scale (sub-national to international level) and availability of data.

1.2 Remote sensing data for REDD MRV

Among those approaches of REDD MRV the application of remote sensing technologies are likely to play leading role. Regarding either deforestation or degradation monitoring can be measured using remote sensing data verified by ground measurements. Optical satellite imagery at multiple resolutions are varies in utilities depended on costs and accuracy. These satellite images require involvement of data analysis. Stepped approach is, optionally, one of the cost-effective approaches using coarse, medium and fine resolutions data, respectively. For example, in a first step coarse resolution (250 m – 1km) data which are high temporal resolution and large area coverage such as MODIS data are useful to identify national-scale hotspots area of forest change. Then further analysis with medium resolution (10-60m) or fine resolution (< 5m) data could be done for detailed analysis.

Although, satellite optical data have been wildly used for forest monitoring, their qualities are still degraded by cloud cover limitation. This study emphasizes the tool which could overcome such serious obstructions. LMF (Local Maximum and Fitting) algorithm (Sawada *et al*. 2005) and our improved LMF filtering were applied to remove cloud effect from the coarse resolution data (eight-day composite MODIS images of Suphanburi province in Thailand). The improved 'Min Max Filter' of the LMF process focuses on using meteorological data to fix window filter sizes. In other words, window filter sizes are, flexibly, depend on weather condition. This improved filter increases efficiency to eliminate the influence of cloud and haze and upgrade qualities of original satellite images. Furthermore, the improved LMF method creates models of the seasonal vegetations changes for these time series MODIS data. These models identify type of forests, forests conditions and type of crops. The abilities of improved LMF technique will be useful for monitoring forests changes. These utilizations will be REDD benefits as well. Although, currently REDD focuses on Landsat data, MODIS is still useful especially to standardize the result of Landsat analysis at countries or regional levels.

2. DATASET

2.1 Study area

Suphanburi province was selected as the study area according to its varieties of land uses like forests and crop-land (e.g. rice, sugarcane, pineapple, cassava). The remaining 60,200 hectares of forest land are 11.24 percent of total area. Deciduous forests and evergreen forests are along the West to the North. Deforestations widely occurred, especially deciduous forests converted to rice and sugarcane field. Various land uses will be useful to create different models for identifying forests and crops.

Suphanburi province is in the Central of Thailand, between latitudes 14^{o}2'43.72" and 15^{o}5'7.72"N longitudes 99^{o}17'21.56" and 100^{o}17'21.56"E. Topography of the province is divided into two zones, plains are in the East, hill to high mountains are along the West to the North. There are three seasons, summer, rainy and winter. Rainy season is about 5-6 months long, usually begins from end of May till mid-October. The heavy rainy months are in September and October, and dry are from November to April. Average rainfall is 1305.4 mm per year, 104 days per year.

2.2 MODIS Land Surface Reflectance data

The first MODIS instrument was launched on the Terra spacecraft in 1999. The second was integrated on the Aqua in 2002. Terra flies in the morning while Aqua flies in the afternoon. The sensors provide high radiometric sensitivity in 36 spectral bands. The used MODIS Land Surface Reflectance in this study called MOD09 Q1/Terra and MYD09 Q1/Aqua version 5 are eight-day composite data with band 1, 2 at 250-meter resolution at nadir. In the eight-day product, the best observation is selected for each pixel. Data used were 46 images per year in 2005, 2006, and 2007. Suphanburi province is in two MODIS land tiles, h27v07 and h28v07.

2.3 NDVI data

The Normalized Difference Vegetation Index (NDVI) indicates the density of green on the observed area contains vegetation. The NDVI is calculated from the difference of reflection in the near-infrared and red regions of the light spectrum. NDVI value ranges from -1 to +1. No green leave gives a value close to zero, whereas higher value shows more density of plant growth.

After preprocessing of MODIS images, NDVI is calculated from surface reflectance of Red band and Near Infrared band as the EQ. (1).

$$NDVI = (NIR-VR) / (NIR+VR) \tag{1}$$

where NIR is Near Infrared surface reflectance, VR is Visible Red surface reflectance.

2.4 LMF Processing

Even though the best observation is selected during the eight-day MODIS data, the effect of cloud and haze still exist. LMF (Sawada et al, 2005) processing, the filtering method of time series data combined with functional fitting algorithm was used to remove those obstructions. We improved 'Min Max Filter' by altering window filter sizes depend on weather condition. LMF harmonic curves showed the seasonal vegetations changes as well.

3. METHOD

After preprocessing, NDVI MODIS data were input to the LMF first step of filtering. Improved Min Max Filtering was used to revise and interpolate time series data. The ideas of improved filtering are using meteorological data to fix the number of window sizes which we use to filter noise at the considering point. The improved filtering methods are divided to 2 concepts, changing window size depends on the average monthly rainfall historical statistical data and depends on the number of continuous cloud-days using cloud mask method.

Concept one is to change window sizes depended on the average monthly rainfall data. The essence is cloud-contaminated probability obviously appeared in rainy day. Experiments of filtering process were done by using only one window size at a time to test which size was properly in the period.

By experiments, Figure 1, window filter size 3 was suitable from February to April 2005, but too small in July 2006, July and August 2007 so they still remained a little noise. Figure 2, window filter size 6 was too big from February to March in 2005 so that Min Max Filter line was over original NDVI, while in heavy rainy month September 2006, window filter size 6 was suitable.

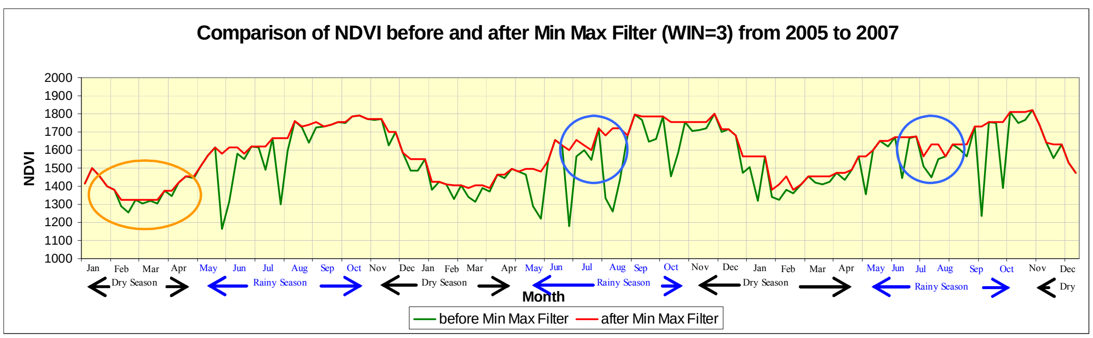

Figure 1: Min Max Filter using window size 3, was suitable in February-April 2005, but too small in July 2006, July and August 2007.

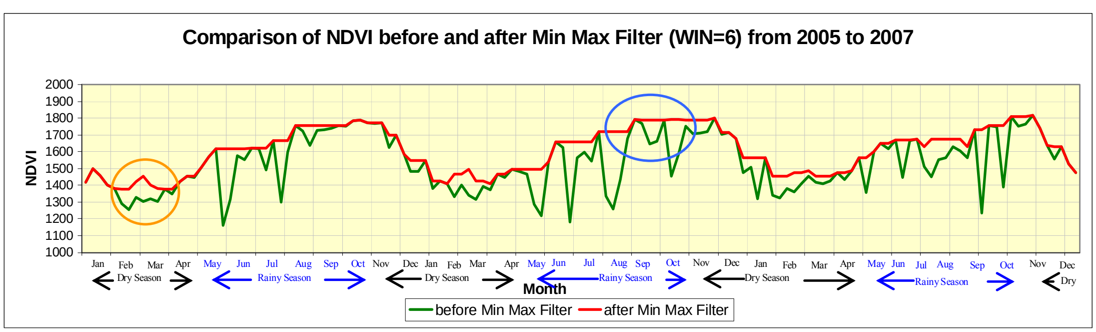

Figure 2: Min Max Filter using window size 6 was too big in February-March 2005, but suitable in September 2006.

Concept two of the improved filtering methods is to change window filter sizes depended on the number of continuous cloud-days using cloud mask method.

Acquired cloud-days data were obtained by defining NIR MODIS Surface Reflectance thresholds of 23 sample images from 46 images in 2007 from TERRA product. By experiments, NIR MODIS Surface Reflectance thresholds from 3000 to 6000, the suitable threshold was 3500. These images were the input cloud mask images in Min Max Filter process.

Figure 3, in the left shows false color image, in the right shows cloud mask image at threshold 3500 of TERRA product, December 2007.

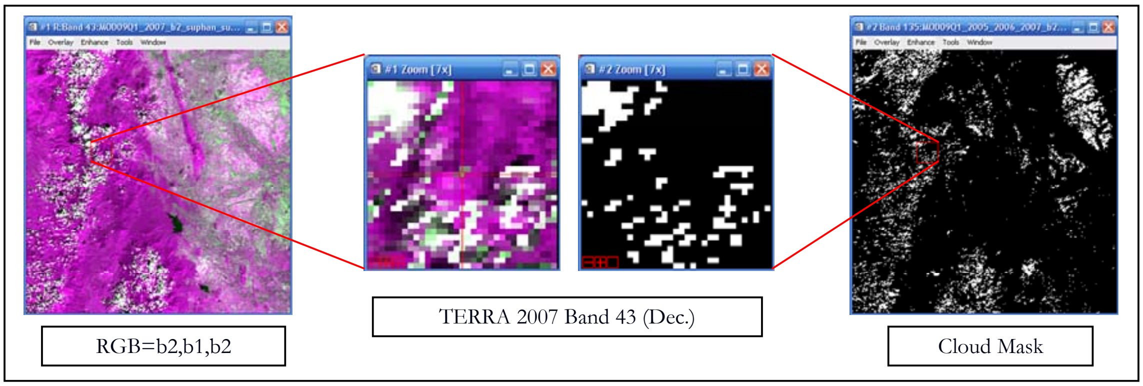

Figure 3: False color image (left), cloud mask at threshold 3500 (right)

4. RESULT AND DISCUSSION

4.1 Result and discussion of improved Min Max Filtering

For the improved Min Max Filtering changing window sizes depended on the average monthly rainfall historical statistical data, the experiments showed the result of appropriate window sizes as three, five, six, five, and three, respectively. 30-year average rainfall in 1961-1990 of Suphanburi province from Thai Meteorological Department was applied to this concept. Therefore, the interpretation of the result was window size 3 for dry season, 5 for rainy season, and 6 for heavy rainy month. The criterion to fix window filter size is shown below.

$0 \leq F_{mean} \leq 100 \rightarrow$ window size = 3
$100 < F_{mean} \leq 200 \rightarrow$ window size = 5
$200 < F_{mean} \rightarrow$ window size = 6
where F_{mean} = Mean Total Rainfall

Consequently, the improved Min Max Filter enhanced original satellite images qualification. Figure 4 and 5 show the results of improved Min Max Filtering refer to two concepts.

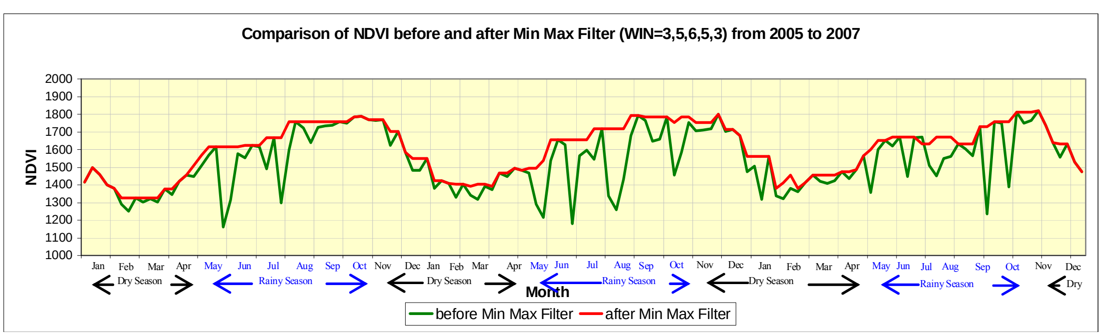

Figure 4: Comparison between the result of improved Min Max Filter using window sizes 3, 5, 6, 5, 3 and Original NDVI.

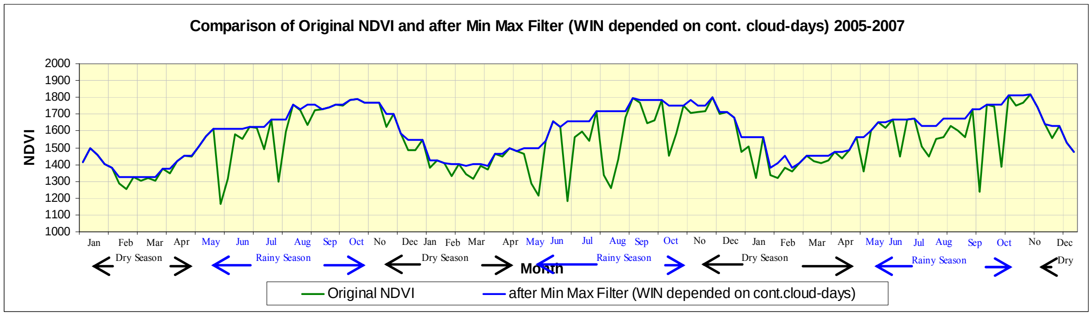

Figure 5: The result of improved Min Max Filter window sizes depended on continuous cloud days.

4.2 Result and discussion of after LMF processing

The filtered images were continued to the next step of the time series fitting model with Fourier formula. LMF harmonic curves showed the seasonal vegetations changes. These models can identify type of forests and crops. Accuracy assessment was verified by ground truth (Kamthonkiat, 2005) and GIS land use map of Suphanburi. The results of after LMF processing are shown below.

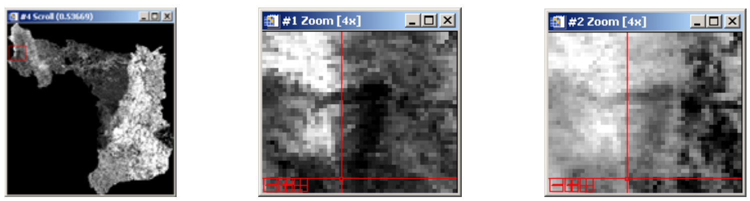

Figure 6: Comparison of original image (middle) and after LMF image of disturbed evergreen forest (right) at the 14° 52' 15.82" lat. 99° 19' 55.18" long.

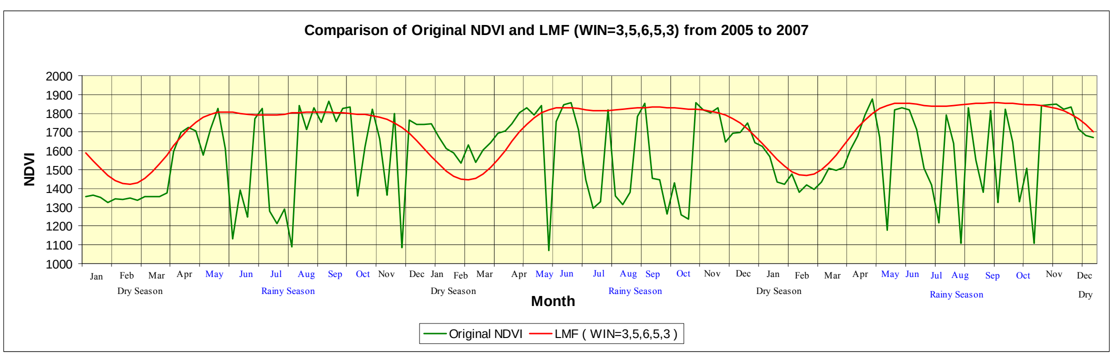

Figure 7: Comparison of Original NDVI and after LMF by plotting through the 14° 52' 15.82" lat. 99° 19' 55.18" long., the pixel of disturbed evergreen forest.

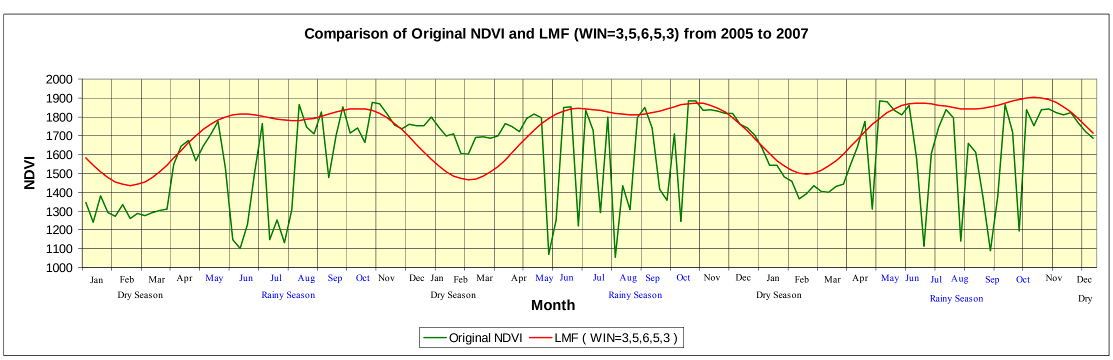

Figure 8: Comparison of Original NDVI and after LMF by plotting through the 14° 49' 1.70" lat. 99° 19' 16.36" long., pixel of disturbed deciduous forest.

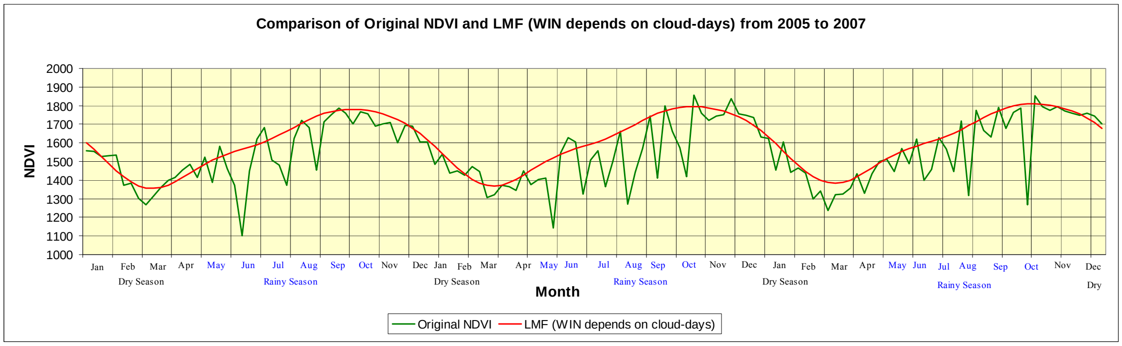

Figure 9: Comparison of Original NDVI and after LMF by plotting through the 14° 12' 16.56" lat. 99° 50' 58.69" long., pixel of Sugarcane.

5. CONCLUSION

Optical remote sensors are significantly beneficial to the measuring, reporting and verifications scheme for REDD. In this study, LMF processing which contains the improved Min Max Filtering was used to eliminate cloud contamination from optical data. The two methods of improved filtering focused on setting window filter sizes according to rainfall data, and to cloud condition. Filtering results overcame noises of cloud and haze and approached more reliable NDVI values. The final results of after LMF models show forests condition and type of forests identification. Besides, the utilities of these models distinguish seasonal changes between forests and crops to detect forests land use changes. This improved LMF processing can be further studied for real annual seasonal changes.

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