Optimizing cloud removal from satellite remotely sensed data for monitoring vegetation dynamics in humid tropical climate

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Abstract. Remote sensing technology is an important tool to analyze vegetation dynamics, quantifying vegetation fraction of Earth's agricultural and natural vegetation. In optical remote sensing analysis removing atmospheric interferences, particularly distribution of cloud contaminations, are always a critical task in the tropical climate. This paper suggests a fast and alternative approach to remove cloud and shadow contaminations for Landsat Enhanced Thematic Mapper$^+$ (ETM$^+$) multi temporal datasets. Band 3 and Band 4 from all the Landsat ETM$^+$ dataset are two main spectral bands that are very crucial in this study for cloud removal technique. The Normalise difference vegetation index (NDVI) and the normalised difference soil index (NDSI) are two main derivatives derived from the datasets. Change vector analysis is used in this study to seek the vegetation dynamics. The approach developed in this study for cloud optimizing can be broadly applicable for optical remote sensing satellite data, which are seriously obscured with heavy cloud contamination in the tropical climate.

1. Introduction

Analyses of vegetation dynamics over large landscape, quantifying vegetation fraction using satellite remote sensing technique is very timely and economically viable [1,2,3]. Remote sensing approach for quantifying and qualifying vegetation fraction through relative measurement and vegetation indices had being applied previously in [4,5,6,7,8].

However, the applicability of this vegetative-fraction derived from satellite remote sensing data is limited to areas that are prone to cloud covers such the tropical rainforest of Malaysia, which lies in the equatorial region that are frequented with heavy precipitation, high temperature and humid throughout the years. In optical remote sensing, removing atmospheric interferences are always critical task in the digital image processing of satellite data for various applications in humid tropical climate. Malaysia where lies in the latitude from 0° to 5° North equator is contaminated of an average of more than seventy five percent of cloud cover throughout the year [9]. Accordingly, the major limitation by using optical remote sensing for the tropical climate applications lies on the least cloud coverage images as it contains persistent cloud cover.

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The aims of the study are to monitor dynamics of vegetation fraction and optimize the use of satellite image in the tropical climate, which is contaminated by heavy cloud coverage using cloud removal technique.

2. Study area

The study area chosen is located in the southernmost of peninsula Malaysia, which is called Johor state, situated at 0° to 6° N and 100° to 106° E latitude and longitude, respectively. The dynamics of vegetation are magnified in such drastically developed area. Iskandar Johor consists of five major river basins; they are Skudai, Pulai, Tebrau, Johor and Layang-laying River Basins. Only Johor River Basin is partially included in Iskandar area. These regions are where the major urban centres of Johor State located, including the Johor Bahru city and surrounding urban centres of Tebrau, Taman Ungku Tun Aminah, and the newly builtup Nusajaya.

3. Materials

Multi-temporal sets of Landsat ETM+ scene of Iskandar Johor area acquired in 2000, 2005 and 2009, were used in this study. It is not necessary to get a total cloud free dataset in this study, but different cloud coverage in the corresponding datasets is needed, so that they able to compensate each other by retrieving area shaded by cloud and their results. Two original ETM+ images for year 2000 were acquired on April 28 and June 30, respectively. TM images for year 2005 were obtained on June 4 and August 5, respectively. Two TM images which used to represent year 2010 were acquired on February and March 12, respectively. Environment for Visualizing Images (ENVI) 4.8, ERDAS IMAGINE 9.2, and ArcGIS 9.3 software packages were used in this study.

4. Methods

The entire methodology used in this investigation is categorized into four phases, including data acquisition, preprocessing and cloud removal, vegetation fraction extraction, and change analysis and quality analysis. Figure 1 illustrates the operational framework of this study as flowchart. In preprocessing phase, the data have been atmospheric restituted, geometric rectified and rescaled. The cloud removal technique was implemented in this stage by the quantifying of vegetation fraction. The vegetation and soil fractions were extracted using Normalized Difference Vegetation Index (NDVI) and Normalized Difference Soil Index (NDSI) for dimidiate pixel method respectively. In last phase, the quality of factions extraction were examined by using theoretically concepts, and vegetation dynamics were analyzed according to vegetation and soil fraction.

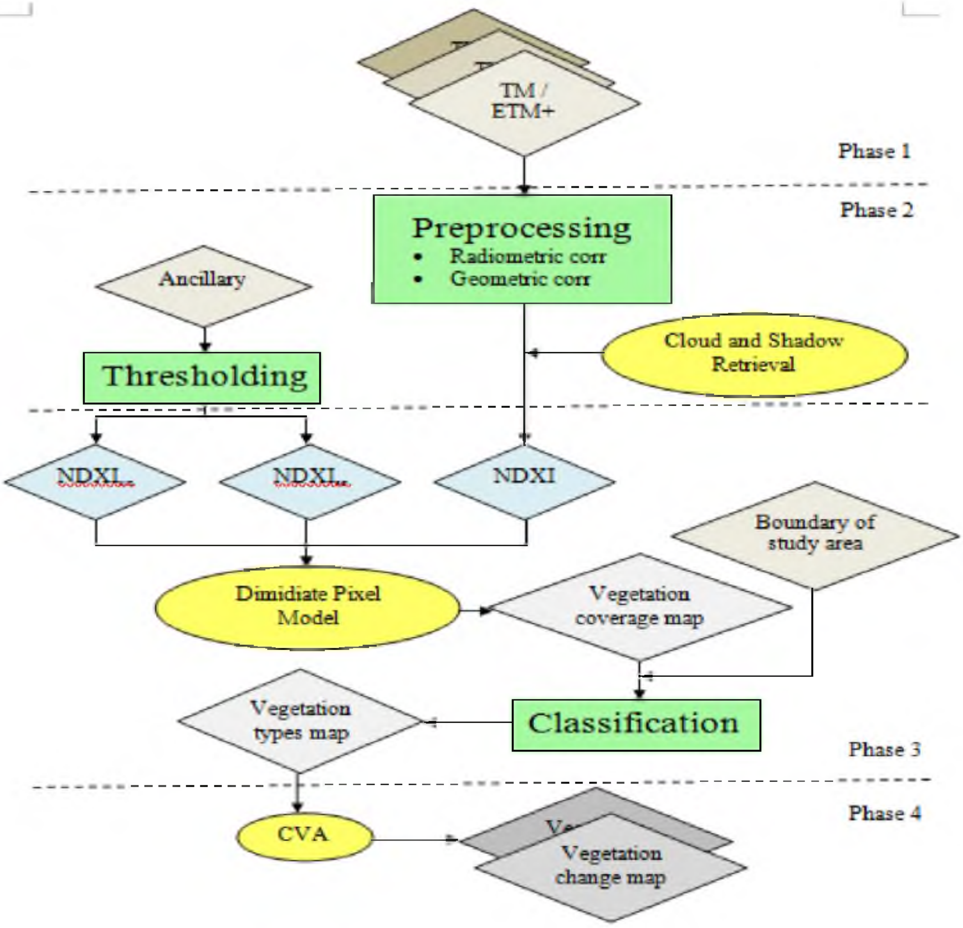

Figure 1. Overview of the methodology framework used in this study.

5. Results and discussion

The essential of cloud and shadow contamination retrieval is magnified in year 2000 dataset. The positions of cloud contaminations are mostly aggregated in east coast of the Johor for Set A image; fortunately the Set B image consists of better or clearer view in east coast area despite it has random distribution of contaminations in other positions other than east coast area. The randomness contamination in Set B is not important because Set A has clear view from the middle area to the west coast. The compensating distributions of cloud and shadow contaminations in these two datasets are advantageous in retrieving a set of clear image in all positions. Year 2000 dataset had retrieved cloud and shadow contaminations up to ten percent for both image sets, which are 14.85% and 11.50% for Set A and Set B, respectively. The final retrieved image for year 2000 by combining two datasets is only remains 4.08% (Fig. 2).

Figure 2. The resultant image after being fused for year 2000.

There is a clear image in year 2005. Year 2005 Set A image is originally consisting of 4.24% cloud and shadow contaminations only, and there is no more better image with the acceptable time interval to represent 2005 dataset. However, the effort to retrieve this 4.24% contamination was still carried on. After all, the 4.24% contamination was reduced 0.55% to 3.69% by using an image (year 2005 Set B) with 23.14% contaminations (Fig. 3).

Figure 3. The resultant image after being fused for year 2005.

The upper area of the 2010 Set A image was contaminated by the clouds up to 11.78%. The contaminations that were successfully being retrieved are only 2.8% to 8.98% as final refined image that used in this study. The reason of this relatively small refinement is the inavailability of image that with the clear view in the same part of 2010 Set A's cloud contaminations in the nearly period year 2010.

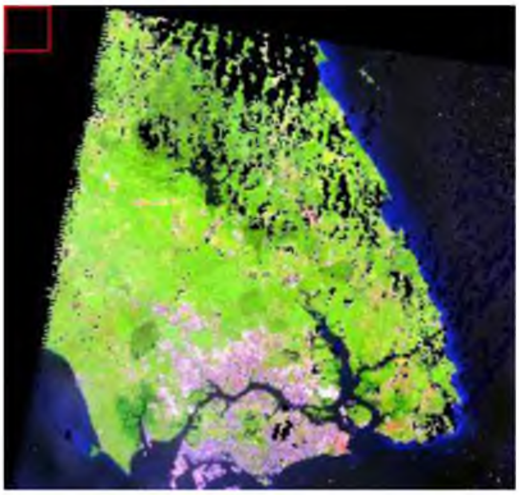

Figure 4. The resultant image after being fused for year 2010.

6. Conclusions

This study proposes fast and alternative way to extract vegetation coverage changes without cloud and shadow contaminations for temporal dates in the tropical climate. Two set of remote sensing satellite data with suitable resolution can be easily used for retrieving cloud and shadow contaminations with different position and distribution. The compensating distributions of cloud and shadow contaminations in these two datasets are advantageous in retrieving a set of clear image in all positions. Change Vector Analysis (CVA) technique can be used for validation the results of the study. The results derived from the case study showed that, in year period 2000 to 2005, there is no much change of vegetation and soil fractions in most of the basins of Iskandar Johor, but changes are just magnified during the year period 2005 to 2010 by showing expanded human settlement areas. Recently, the extension of the settlement areas is associated with reducing the vegetation converges and degradation from very dense vegetation fraction to moderate or dense vegetation in the study area.

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