Temporal Forest Change Detection and Forest Health Assessment using Remote Sensing

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Abstract This paper presents the detection of Angsi and Berembun Reserve Forest change for years 1996 and 2013. Forest is an important part of our ecosystem. The main function is to absorb carbon oxide and produce oxygen in their cycle of photosynthesis to maintain a balance and healthy atmosphere. However, forest changes as time changes. Some changes are necessary as to give way for economic growth. Nevertheless, it is important to monitor forest change so that deforestation and development can be planned and the balance of ecosystem is still preserved. It is important because there are number of unfavorable effects of deforestation that include environmental and economic such as erosion of soil, loss of biodiversity and climate change. The forest change detection can be studied with reference of several satellite images using remote sensing application. Forest change detection is best done with remote sensing due to large and remote study area. The objective of this project is to detect forest change over time and to compare forest health indicated by Normalized Difference Vegetation Index (NDVI) using remote sensing and image processing. The forest under study shows depletion of forest area by 12% and 100% increment of deforestation activities. The NDVI value which is associated with the forest health also shows 13% of reduction.

1. Introduction

Reserve forest in Negeri Sembilan as of 2011 is 154,577 hectare which includes 24% of the state’s land cover. There are 21 reserve forests here and among them are Angsi and Berembun with approximately 34,000 hectares in combine. Remote sensing is the science of acquiring information about the earth's surface without actually being in contact with it. Remote sensing technology involve the use of sensor placed on a platform moving at a distance from earth’s surface and it can be used for collecting data of the earth for the purpose of inventorying and monitoring. Remote sensing is done by receiving and recording energy that is either emitted or reflected by the surface of the earth, so there must be a source of electromagnetic energy, a target, and a sensor.
Reflectance is the percentage of light hitting a material that is then reflected by that material. These patterns of reflectance and absorption across wavelengths can uniquely identify certain materials. A chemical compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Leaves appear green when chlorophyll content is at its maximum. When there is less chlorophyll in the leaves, there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear yellow. The internal structure of healthy leaves act as excellent diffuse reflectors of near-infrared wavelengths. The sensor receives the reflected energy and it is transmitted to a receiving and processing station where it is converted into digital data which are then converted into images using computer models. In Malaysia command operational satellite used are Radarsat, Landsat, SPOT, Quick Bird and IKONOS. Finally, the images are interpreted to extract information about the target.

Normalized Difference Vegetation Index (NDVI) shows patterns of vegetation growth by indicating the quantity of actively photosynthesizing biomass on a landscape [1]. Measuring and monitoring NDVI is one way that scientists can determine how healthy or unhealthy vegetation may be. There are many factors that can cause the disruption of the health of forests. These can be categorized into living (biotic) and non-living (abiotic) factors. Biotic agents include fungi, bacteria, viruses, insects, and larger animals. Non-living factors are related to weather, water, soil conditions, mechanical agents, and chemicals such as atmospheric pollution [2]. The main goal of this project is to detect forest temporal change using remote sensing application. The remote sensing images are processed and analyzed using Erdas Imagine and ArcGIS software. The NDVI process enables the health of the forest for both years to be analyzed and compared to see their changes over 17 years.

2. Methodology
The method flow of performing this project is divided into several parts. They are:

2.1 Data Collections
Data and information are collected from various sources, namely Malaysian Remote Sensing Agency (Macres), Department of Environment and Forestry Department of Negeri Sembilan. Satellite images used in this study are Landsat-5 TM image year 1996 and SPOT 5 image year 2013 with 2 points latitude and longitude of 2.7, 101.9 and 2.6, 102.2. The images are given with compliment from Macres for this project.

2.2 Image Processing
The raw satellite images were first being pre-processed with radiometric and geometric corrections using Erdas Imagine. Radiometric correction is a process to replace missing or bad lines and to reduce haze. Geometric correction or rectification is the process of projecting the data onto a plane and making it conform to a map projection system. Georeferencing means assigning map coordinates to the image data. Then the images were classified to give a clear view of forest area and forest depletion area in term of deforestation. Supervised classification is identification in the imagery homogeneous representative samples of the different surface cover types or information classes of interest. The 1996 and 2013 images were supervised the categorization of the set of specific classes that are forest, water, deforestation and urban. The images were subset to focus on the study area only. Both images that have been preprocessed and classified were then compared and the resultant image was to be study and analyzed to see the temporal changes between them. Image analyzation is done using ArcGIS software.

2.3 NDVI Process
This process is done to get the value of NDVI of the forest for year 1996 and 2013 and to compare the NDVI value of each image. NDVI values show how the quality and relative health of the forest.
To investigate the health of the forest, NDVI process was done for both images. The NDVI is the difference of near-infrared (NIR) and visible red reflectance values normalized over reflectance. Before getting the NDVI image, the raw image which is in digital number must be changed to radiance image. The following general equation is used to convert Digital Numbers (DNs) to radiance (L):

\[ L_\lambda = \text{"gain"} \cdot QCAL + \text{"bias"} \]

(1)

This is also expressed as

\[ L_\lambda = \left( \frac{(\text{LMAX}_\lambda - \text{LMIN}_\lambda)}{(\text{QCALMAX} - \text{QCALMIN})} \right) \cdot (\text{QCAL} - \text{QCALMIN}) + \text{LMIN}_\lambda \]

(2)

Where
- \( L_\lambda \) = Spectral Radiance at the sensor’s aperture
- \( \text{LMIN}_\lambda \) = the spectral radiance that is scaled to QCALMIN
- \( \text{LMAX}_\lambda \) = the spectral radiance that is scaled to QCALMAX
- QCALMIN = the minimum quantized calibrated pixel value (corresponding to LMIN\( \lambda \)) in DN
- QCALMAX = the maximum quantized calibrated pixel value (corresponding to LMAX\( \lambda \)) in DN
- QCAL = the quantized calibrated pixel value in DN

The process of changing DN image to radiance image is built in Erdas Imagine model maker. The process is repeated to get radiance image for both year 1996 and 2013. After that, the image in radiance is converted to reflectance while performing atmospheric correction as well. The calculation is as follows:

\[ \rho_p = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN\lambda \cdot \cos\theta_s} \]

(3)

Where
- \( \rho_p \) = Unitless planetary reflectance
- \( L_\lambda \) = Spectral radiance at the sensor’s aperture
- \( d \) = Earth-Sun distance in astronomical units
- \( ESUN\lambda \) = Mean solar exoatmospheric irradiances
- \( \cos\theta_s \) = Solar zenith angle in degree

\[ \cos\theta_s = 90^\circ - \text{sun elevation} - \text{incident angle} \]

(4)
The process of changing radiance image to reflectance image is built in Erdas Imagine model maker using formula (3). The process is repeated to get reflectance images for IR and NIR band for both 1996 and 2013 images. After converting both images to reflectance, NDVI process can be proceed in the model maker. Specifically,

$$\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}$$  \hspace{1cm} (5)

To interpret NDVI value, Table 1 shows reference NDVI values for different land areas [3]. NDVI for vegetation range value is from 0.1 to 1. NDVI value of 0.4 to 1 is commonly associated with rainforest area.

| Different Land Areas       | NDVI Values | NDVI Values (X) |
|----------------------------|-------------|-----------------|
| Water                      | Negative    | X < 0           |
| Rocks/Sand/Snow            | Values Close to 0 | 0.1             |
| Greenery/Vegetation        | Low Positive | 0.1 < X < 0.4   |
| Tropical Rain Forest       | Values       | X \to 1        |

### 3. Result

#### 3.1 Image Classification and Change Detection

The study area is classed into several major classes using supervised classification method. The supervised classification is done for both 1996 and 2013 image. The distribution of classes for each image is graphed. These two images are then compared to see the percentage of changes for each class.

The supervised classification of 1996 Landsat-TM 5 image is depicted and the percentage of distribution areas is shown in Figure 2. The classification distribution chart shows the forest area covers 87% of the whole study area while deforestation, urban and water body cover 7%, 4% and 2% of the whole area respectively.

Applying the same classification method, Figure 3 depict classification distribution chart for year 2013. From the distribution chart of Figure 3, forest area covers 77% of whole study area, deforestation covers 14% while urban and water body cover 7% and 2% of the whole area respectively. The depletion of forest in this study area from year 1996 to 2013 is noticeable. The temporal forest change can be seen with depleting of 12% of forest area which is approximately 4080 hectares of forest reduction. On the other hand, deforestation area increased alarmingly up to 100% from 7% to 14%. The urban area and water body are also increased to 75% and 40% respectively.

The differences between percentages of classification distribution for year 1996 and 2013 show the changes of study area.
The change detection for both image are processed and the resultant change detection image is depicted in Figure 5. Figure 4 shows ranges of change based on pixel value from 0 to 1. Light yellow shows little changes, red shows medium changes and blue shows highest changes. The intact forest shows orange in colour which means there is a light change of forest while the deforestation shows blue in colour which means big changes. The urban area shows red means medium changes during the 17 year period.

3.2 NDVI Change Detection and Forest Health

Besides considerable changes of forest area, the health of the forest also shows decrement in term of NDVI. Figure 6 shows the NDVI change image for year 1996 and 2013.

Figure 6. NDVI change for year 1996 and 2013

Figure 6 shows the level of NDVI change detection image. The decrement of NDVI of the forest can be seen with vast brown and light brown colour of the forest area. The increment of NDVI for water body, settlement and urban area which are showed in green colour can be ignored as NDVI is only applicable for vegetation monitoring. It can be seen that almost the whole forest experience NDVI decrement for the 17 years period. The comparison of NDVI statistic for year 1996 and 2013 are shown in Table 2. This comparison shows NDVI statistical value change for both years.
From Table 2, it can be seen that the overall NDVI value is 0.5 which is acceptable for tropical rain forest. In 1996, the mean, median and mode of the NDVI value are 0.541, 0.58585 and 0.59862 respectively. In 2013, all of the mean, median and mode value shows reduction with 0.473, 0.50024 and 0.49472 respectively. The difference of statistic data for both images shows reduction of mean, median and mode with 0.07, 0.091411 and 0.10094 respectively. The mean NDVI value indicates the decreasing of almost 13% of forest health from year 1996 to 2013.

Considering the reduction of forest health due to atmospheric pollutant [2] and air pollutants probed were positively correlated with urban built-up density [3], a set of ambient air quality samples are taken from new road construction at Angsi Reserve Forest from year 2004 to 2008 to see how deforestation and construction affect the ambient air quality thus affecting the forest health. Figure 7 shows the air quality reading during the construction period.

There are 3 stations collecting the air quality data namely A1, A2 and A3 are located at Taman Seri paroi, Ulu Bendol Recreation Park and Taman Seri Bendol respectively. A1 and A2 stations are located near the deforestation area for the road construction project while A3 located further away from the deforestation area.

Air pollutant index (API) indication: 0-50 as good, 51-100 as moderate, 101-200 as unhealthy and 2001-300 as very unhealthy. The graph shows increasing Total Suspended Particulate (TSP) during
the road construction in year 2004 to 2008. The API readings show increasing values to moderate level and there is a time when the value nearly approaches unhealthy level. It proves that air pollution is directly connected with deforestation and urbanization and the reduction of forest health in this study is directly connected with air pollution due to deforestation and urban built up.

4. Conclusion
Based on the remote sensing and image processing analysis, it can be concluded that the forest study area shows a considerable changes from year 1996 to 2013. The NDVI value which is associated with forest health also decreases over the 17 years period. The health of forest is known to be affected by air pollution is tally with API index during deforestation and construction period which shows high API index recorded. The changes of study area are important to monitor forest change so that the deforestation and development can be planned and the balance of ecosystem is still preserved.

5. Recommendation
For future research, the forest change detection can be studied by creating spatial models using ArcGis and its extension Spatial Analyst. Then the factor of changes can be determined and the statistical factor of changes can be analyzed.

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