Detection of deforestation on protected forest areas using multi-sensor platform and time series analysis – An environmental monitoring tool

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ABSTRACT: Monitoring of deforestation and forest degradation is critical on the biodiversity, and various ecological aspects, especially in a tropical country like the Philippines. Watershed as one of the Protected Forest Areas, supports many communities around the metro for their supply of drinking water, irrigation, agriculture and manufacturing. Changes in land cover, especially deforestation may have a significant effect on watershed hydrology and as well as the quality and cleanliness of its water. pace borne remote sensing can be used as an accurate and cost-effective way to monitor changes on large forested cover and geographic areas.

This paper describes the methodologies to develop an automated tool that can monitor and alert possible deforestation on protected forest areas such as watersheds. The study area for this paper is focused on the Angat Dam watershed located in the Province of Bulacan in the Philippines which provides water supply to the people of Metro Manila, the capital of the country and its nearby provinces.

Through the use of open source remotely sense data Sentinel 1A that can capable of capturing C-band Synthetic Aperture Radar (SAR) imagery and Multispectral satellite images from dove satellite, this paper highlights the development of an automated workflow using remote sensing indices such as the Normalized Difference Vegetation Index and the applications of Dynamic Time Warping to detect forest loss over the area of study.

The output of this paper shows where are the points and locations of possible deforestation based from a series of remotely sensed data.

Using this kind of tool, mandated agencies for forest management can able to monitor on a nationwide scale the possible locations of deforestation through an alerting system integrated based from the outputs of the developed algorithm.

1. INTRODUCTION

The Philippines is a country that is rich in natural resources and has gifted with many kinds of natural water forms such as bays, rivers, lakes, falls, gulfs, straits and swamps. Aside from these water bodies, Philippines was also gifted by frequent visits of typhoons and heavy rain monsoons which may result to flooding, landslides and other health related problems. Even though that with this kind of natural phenomena that is regularly happening to our country we need to also to consider that these events produce water and water is the nature's best gift for us because people needed freshwater for many purposes. These freshwaters are naturally stored and originate on Watersheds.

Watersheds is defined as a land area which drains into a stream system like lake, river wet-land and other water ways. If properly managed, watersheds can supply water for different agricultural and industrial use. (Fox, 2018)

The Philippine watershed areas are already in critical condition and deforestation contributes a lot in the degradation of almost 2.6 million hectares of identified critical watershed areas within the country. The destruction of rest and uplands endangers the watershed and results in massive soil erosion, declining soil productivity, sedimentation of river channels and siltation of dams, heavy flooding and acute water shortages during dry season (Paragas, N.D.)

Out of these watershed areas are some 127 proclaimed watersheds which are intended to be managed and protected since these critical areas are source of water to supply irrigation systems, hydro-electric dams, and domestic, as well as industrial, water systems or existing water facilities (Castilo, 2010).

Remotely sensed data from satellites has been widely used for various application especially in the environmental monitoring application. It is a very powerful tool in the provision of such information since it covers lot of area and cost efficient among other deforestation monitoring actives. With the use of open source satellite images from the Sentinel 1A/1B and Sentinel 2A/2B, this paper will explain various methodologies and techniques that can be used to develop a tool for detecting possibility of deforestation over a wide range of area.

2. Study area

For this study, the area of focus will be on the Angat dam watershed. Angat dam watershed is very important especially to the residents of Metro Manila and nearby province of Bulacan. The 62,300-hectare Angat Watershed Reservation lies at the Southernmost tip of the Sierra Madre mountain range and straddles the towns of Dona Remedios Trinidad, Norzagaray, and San Jose Del Monte in Bulacan. Its principal river, Angat River, supplies water to both the Angat Dam and the La Mesa Dam.

Angat Dam irrigates more than 30,000 hectares of prime agricultural lands in Bulacan and feeds some 200 Megawatt of hydroelectric power to the Luzon grid. The Angat watershed also brings domestic water to some 12 million people of Metro Manila through the La Mesa Dam (DENR Region III).

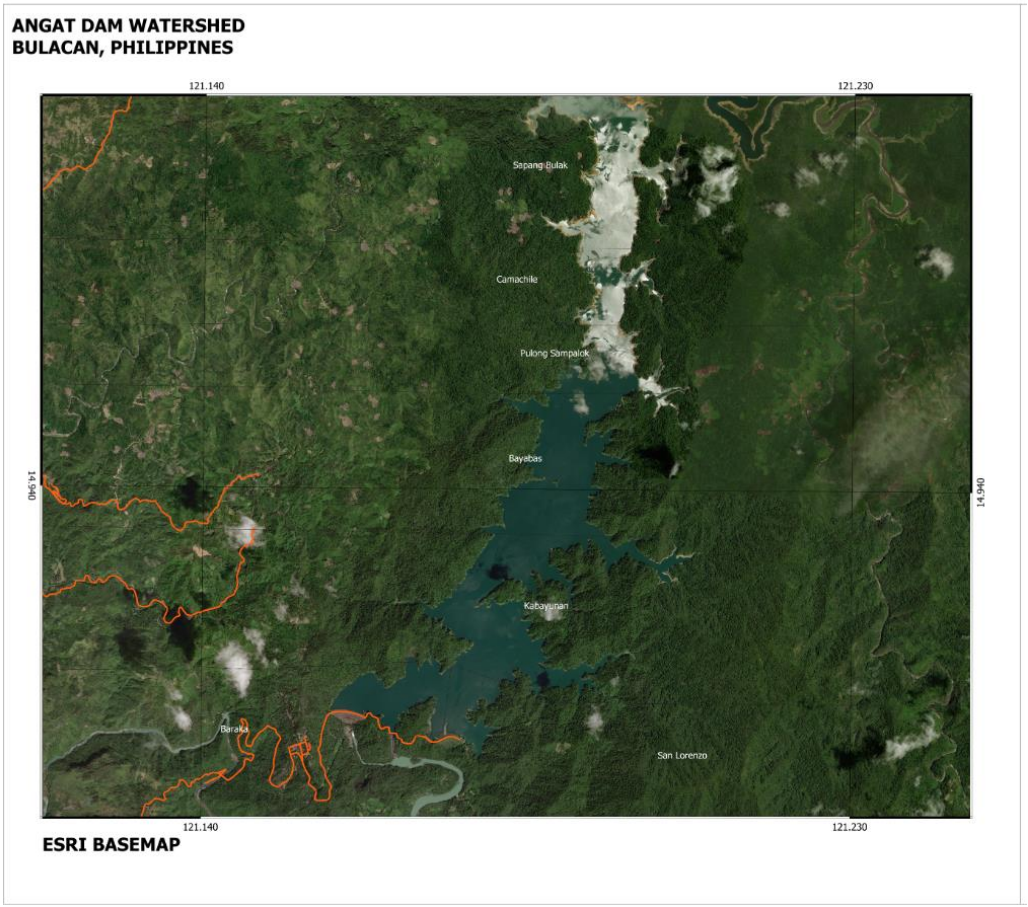

Figure 1: A base map of the Angat dam watershed that will be used as a sample area for this study

The Angat watershed is also considered as category IV (protected area with sustainable use of natural resources) by the International Union for Conservation of nature and considered as well as a protected area by the DENR

Being as a protected area It considered illegal to do any kind of logging and other activities in the area that may damage its ecosystem and environment. However even though it is protected by the law there are numerous news that are coming out from the people who lived for a long time in the area which also serves to protect the place from illegal activities encounter harassment from illegal loggers.

According to Dumagat forest rangers "Almost every day, for the past ten years, illegal logging, timber poaching, charcoal-making and slash-and-burn farming have been reported in areas around the Ipo and Angat Dam watershed areas (Estrope 2018).

With the use of remote sensing technology, vegetation and forestation activities overt the area can be achieved through development of automated workflows and analyzing information based from synthetic aperture radar and multispectral satellite images

And With the use of remote sensing technology to monitor vegetation activities over the area using automated workflows and analyzing the information we could get from the multispectral images for satellite.

3. Data used

The data that will be used for this study will be from the European Space Agency's synthetic aperture radar satellite imagery Sentinel 1, multi-spectral satellite imagery Sentinel 2 and the dove

satellites from Planet Labs.

3.1 Sentinel 1

Sentinel 1 is first of the Copernicus Program satellite constellation of the European Space Agency and it is composed of a constellation of two satellites Sentinel 1A and Sentinel 1B and they operating day and night performing C-band Synthetic aperture radar image enabling to acquire satellite image regardless of weather with a revisit time of 12-days per each of the two satellites (European Space Agency, 2012)

3.2 Dove Satellite

The dove satellite constellation is a fleet of nanosatellites operated by Planet Labs Inc. and has the capability to capture up to 2 million square kilometers of imagery per day. It has a high-resolution multispectral imaging capability up to 3 to5 meters ground sample distance. (Planet Labs, 2015)

4. Methods

Extracting intelligent information from the sensor of remotely sensed data is very useful in pin pointing ground features. On this section will be explained various methodologies and remote sensing techniques applied in order to come up with a tool that could be used to automatically detect possible deforestation on protected areas.

4.1 A Time series approach using Sentinel 1A imageries

A time series of sentinel 1A was acquired for the whole year of 2018 over Angat Dam watershed. All the satellite images were pre-processed on a chain of workflows for them to become analysis ready.

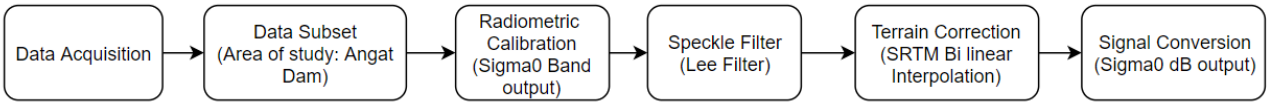

Figure 2: Pre-Processing chain workflow for Sentinel 1 images

As shown in Figure 2 is a chain of workflow applied to all the 29 time-series of images acquired by GRD Sentinel 1A images from January to December of the year 2018. All the data was subset and focused on the Angat Dam watershed. After subset, the images where radiometrically calibration and extract the Sigma naught values. Speckle lee filter was also applied to remove noise on the SAR image, Ground Terrain correction was applied to further improve the calibration of images and lastly the DN signals are converted to Sigma naught dB output to get the average intensity per pixel of image

The next step to determine possible deforestation is to know the backscatter values of determined deforested areas. Using SAR imagery alone, it is quite difficult to determine immediately the possible areas being deforested but with pixel comparison from backscatter values of time series SAR images and time series images of Multi-spectral images, threshold values can be extracted to determine the backscatter values that could lead to possible deforestation over an area.

4.2 Determining SAR image threshold values using Multispectral imagery

The next step to determine possible deforestation is to know the backscatter values of determined deforested areas. Using SAR imagery alone, it is quite difficult to determine immediately the possible areas being deforested but with pixel comparison from backscatter values of time series SAR images and time series images of Multi-spectral images, threshold values can be extracted to determine the

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With the use of Normalized Difference Vegetation Index (NDVI) applied on the multi-spectral images, that health of vegetation over an area can be assessed quantitatively. NDVI is a simple graphical indicator that can be used to analyze remote sensing measurement specifically focused on Vegetation health and it is widely used for agricultural and forest monitoring.

To compute NDVI, a remote sensing instrument must have the capability to capture multispectral images specifically the Red band and the Near-infrared bands because healthy vegetation reflects Nearer-more Infrared and green light compare to other wavelengths, but it absorbs more red and blue light. It is the reason why human eyes see vegetation as the color green, and if human eye can also see near-infrared then it would be very strong for vegetation too (Pettorelli, 2005).

With the characteristic of the Near-infrared wavelength and Red wavelength to the vegetation, NDVI can be computed using this formula. adapted from 'Measuring vegetation (NDVI and EVI)', by J. Weir, 2000

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{Red})}{(\mathrm{NIR} + \mathrm{Red})}$$

NDVI values ranges -1 to 1 and each number indicates how healthy vegetation on the areas captured by the sensor.

NDVI categorized values (Weir, 2000):

-1 to 0.2 = Barren
0.2 to 0.3 = Low Vegetation
0.3 to 0.4 = Medium Vegetation
0.4 to 0.5 = Vegetated area
0.5 to inf = High Vegetated area

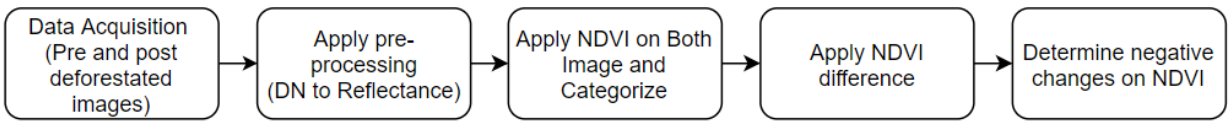

Figure 3: Workflow for determining deforested area using categorized NDVI

The resulting categorized NDVI difference based from the workflow shown in figure 3 can be used to determine deforestation over a certain area.

4.3 Multi-sensor cross analysis using Multi-spectral images for determining threshold to be used for deforestation monitoring using SAR images

Since Philippines is a tropical country blessed by clouds, monitoring deforestation over protected areas can be quite challenging since Philippines is generally always cloudy. With the use of multi-sensor cross analysis from SAR and Multi-spectral satellite images, the needed threshold for SAR backscatter values can be determined to detect possible deforestation.

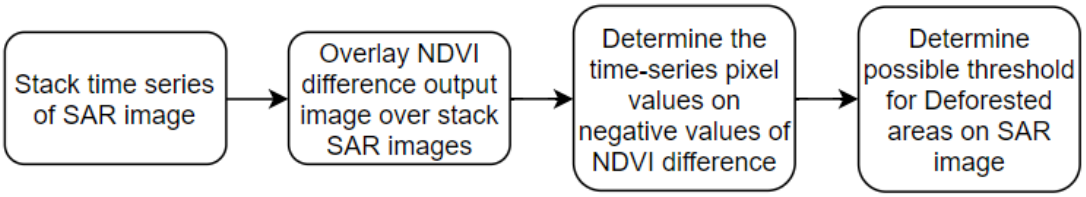

Figure 4: Workflow for Multi-sensor cross analysis between SAR and Multi-spectral image in determining possible deforestation

The resulting values from the workflow shown in figure 4 will be used to determine possible deforestation over a series of SAR images.

4.4 Masking of unnecessary Areas

It is important that unnecessary areas should be masked out such as bodies of water, non-forested areas and built-up areas. Masking this area could prevent false positive or negative results from the processing of satellite images.

5. Results

This section shows the outputs based from various methods applied to determine possible deforestation over a certain area

5.1 NDVI change results.

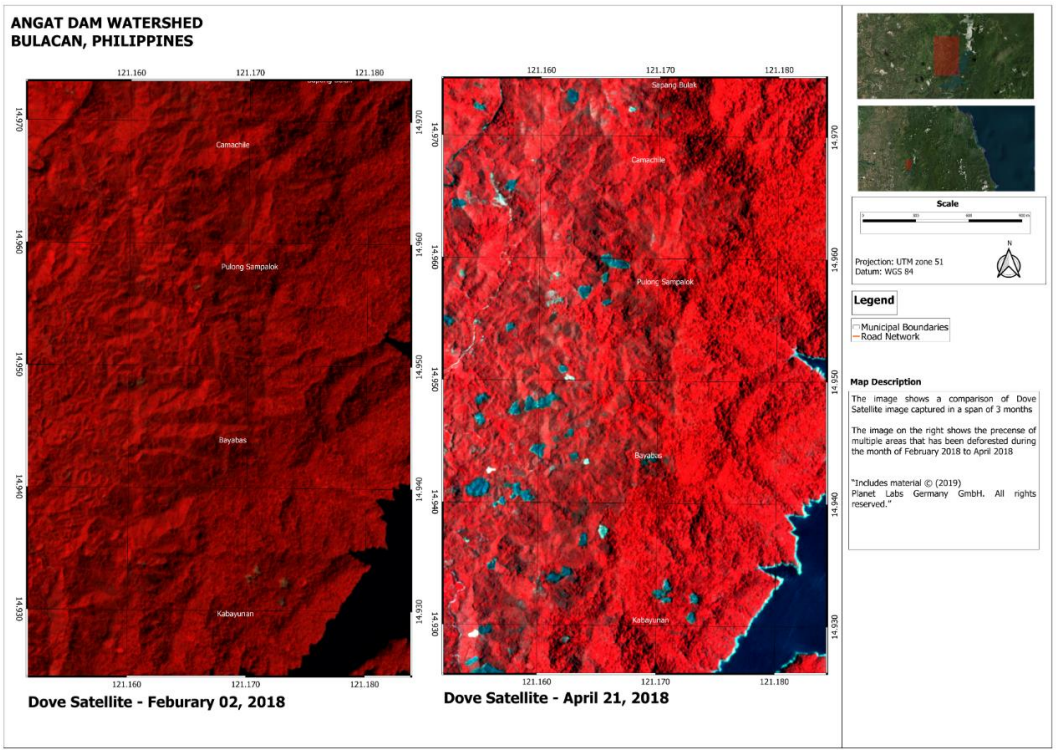

Figure 5: A False color satellite image comparison over Angat Dam watershed shows multiple areas that has been deforested.

Two multispectral satellite images acquired last February 02, 2018 and April 21, 2018 is used determine possible deforestation over Angat dam using NDVI categorization and NDVI difference Categorization.

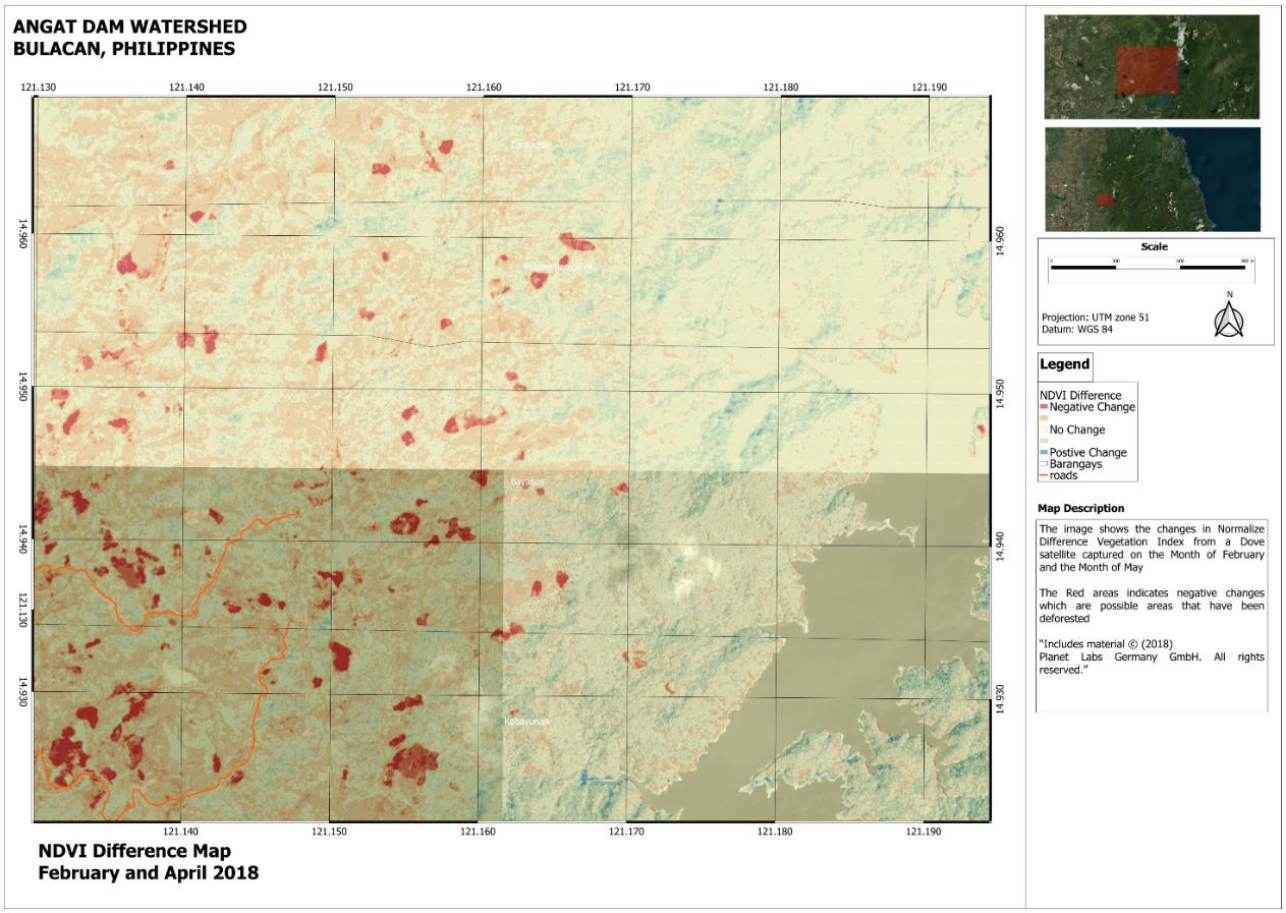

Figure 6: NDVI Difference map that shows possible deforestation over Angat watershed

The areas that are colored in red are areas that have negative values based from the computation of NDVI difference between two images that was captured last February 2018 and April 2018. The areas in red will be used to determine thresholds for deforestation that will be applied on the time-series of SAR images.

5.1 Multi-sensor cross analysis

The determined deforested areas based from computing NDVI difference is processed and analyzed together with the time-series of Sentinel 1A images that was captured for the whole year of 2018. Random samples have been selected and will determine thresholds that can be used to automatically detect deforestation on a certain Sentinel 1A image.

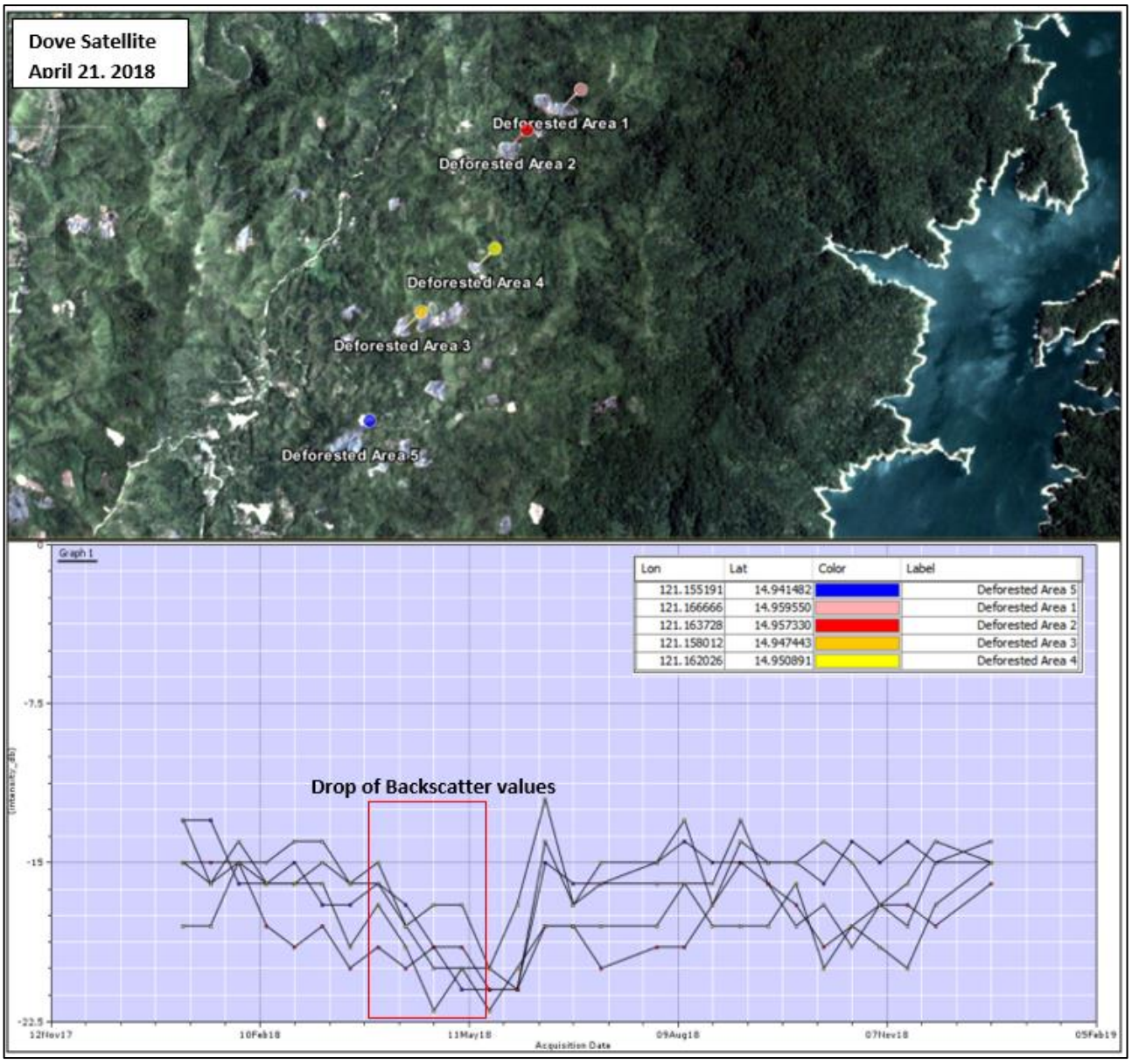

Figure 7: Observed drop of backscatter values during the month of April and May on the noticeable deforested areas based from a Dove satellite image taken last April 21, 2018

Based from the observation shown in figure 7. The time-series plot from the five samples on determined deforested areas based from NDVI calculations shows a drop of backscatter values at around the month of March, April and May of 2018. These graphs indicate that there is a possibility that during the dropping of backscatter deforestation is starting already in the area until the areas are completely depleted of forest resources.

In line with the graph shown, a threshold value of around -19db to -22db can be used to extract possible deforestation over a series of SAR imageries

Increasing values of backscatter also indicates that the missing vegetation over the areas was being replaced by probably another type of vegetation.

6. Conclusion

The resulting study shows that by monitoring changes in backscatter values on a time-series of Synthetic aperture radar images. Deforestation can be determined. On the case of the Angat dam watershed, the sudden drop of backscatter and values and increased again through shows some

possible evidence of slash and burn farming where a forested land is cleared cut and any remaining vegetation is burned resulting a newly cleared land with nutrient rich layer to help fertilize vegetation. This could probably the reason why after a sudden drop of backscatter value was able to achieve again higher value of backscatter due to vegetation regrowth.

Since Angat Watershed is a protected area, this kind of activity must be monitored and with the used of this technique, it can be applied on vast amount of area needed to be monitored.

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