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# Comparison results of forest cover mapping of Peninsular Malaysia using geospatial technology

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**Abstract.**Climate change and global warming transpire due to several factors. Among them is deforestation which occur mostly in developing countries including Malaysia where forested areas are converted to other land use for tangible economic returns and to a smaller extent, as subsistence for local communities. As a cause for concern, efforts have been taken by the World Resource Institute (WRI) and World Wildlife Fund (WWF) to monitor forest loss using geospatial technology – interpreting time-based remote sensing imageries and producing statistics of forested areas lost since 2001. In Peninsular Malaysia, the Forestry Department of Peninsular Malaysia(FDPM) has conducted forest cover mapping for the region using the same technology since 2011, producing GIS maps for 2009-2010,2011-2012,2013-2014 and 2015. This paper focuses on the comparative study of the results generated from WRI,WWF and FDPM interpretations between 2010 and 2015, the methodologies used, the similarities and differences, challenges and recommendations for future enhancement of forest cover mapping technique.

## 1.Introduction

Deforestation has been identified as one of the many contributing factors to climate change[5]. Keeping forests intact throughout the world has become a major focus and concern for scientists and environmentalists, as well as governments, as their deterioration in terms of size and quality may produce unwanted domino effects to the stability of the earth. While developed countries have generally ceased from opening their remaining forests due to their economic prosperity, developing countries with natural forests continue to exploit these land banks as an important source to spur their economic growth towards achieving similar developed status. This came into the limelight in 1992, when the United Nations Conference on Environment and Development (UNCED) was held in Rio De Janeiro, resulting in the manufacturing of agreements and guidelines for sustainable development that stressed on sustainable forest management [9].

For Malaysia, this comes in the form of submission of remaining forest area status reports at regional and global levels on specified periodical basis such as through the Country Report for the Convention on Biodiversity (CBD), Forest Resource Assessment (FRA), Monitoring, Assessment and Reporting (MAR), ASEAN Senior Officers of Forestry (ASOF) and ASEAN Ministers on Agriculture and Forestry (AMAF). The report can also be used as base information for the country if it decides to pursue the carbon stocking scheme such as the Reducing Emissions from Deforestation and Forest Degradation (REDD) which may provide monetary incentives through conservation and rehabilitation efforts of the country's forests[10].

The availability of remote sensing temporal satellite images in combination with GIS have opened a new dimension in forest cover change detection where official statistical information of particular areas of forest extent derived from conventional methods can be scrutinised and verified. For almost the past two decades, geospatial technology has been used by the government authorities such as the Forestry Department of Peninsular Malaysia (FDPM) in Malaysia for the planning, managing and monitoring of its forest area and world-based non-governmental environmental organisations such as World Resource Institute (WRI) and World Wildlife Fund (WWF) for their work including tracking the deforestation trends in temperate and tropical countries with still large traits of forest including Malaysia as part of the check and balance process in safeguarding the remaining world's forests. In this paper, a comparison of forest cover loss results from 2001 to 2015 produced by WRI,WWF and FDPM , wherever possible, is made to assess its accuracy. The FDPM's geospatial data used in this paper are research data, as it is not used as an official data in any publication by the organisation.

## 2. Forest, forest cover and Permanent Reserved Forest

The definition by the United Nation's Food and Agriculture Organisation (FAO) [1] of "Forest" is 'a land area not more than 0.5 ha with a tree canopy cover of more than 10% which is not primarily under agricultural or other specified non-forest use, and in young forests and regions where tree growth is climatically suppressed, the trees should be capable of reaching a height of 5m *in situ*.' The definition is generally accepted, including for Malaysia. The Forestry Department Peninsular Malaysia (FDPM) has published their forested area statistics for Peninsular Malaysia since the establishment of the entity during the colonial days. The initial base information of the forest areas was extracted from the topography maps of the Land Survey Department and the Standard Sheet maps of the Land Offices. Eventually the maps and statistic information were updated by the State Forestry Departments (SFDs) in form of deductions and additions on the statistical information whenever a forest area is approved for conversion to non-forest use or development or degazettement of a Permanent Reserved Forest (PRF), or a gazettement is made for a new Permanent Reserved Forest(PRF). The conventional method involved the use of manual measurement and calculations of charted areas on hardcopy maps to come up with the forest area figures. The importance of an area on the map tallying in size with its stated area statistic is important to maintain the integrity of the data, and this can be made possible through the use of computerised methods. In 2011, FDPM embarked on a pilot forest cover mapping project for Peninsular Malaysia using geospatial technology aiming to compare the acreage size of an area polygon with the ones generated traditionally. The initial definition for forest cover used was: 'Land covering an area of more than 0.5 ha with trees having height of more than 5 meters at maturity and with canopy coverage of more than 30% or trees enable to reach the thresholds mentioned *in situ* derived from satellite images. Excludes land dominated for agriculture and urban purposes but include water bodies.'As the project progresses, FDPM later redefined forest cover as 'Land covering an area of more than 0.5 ha with trees having more than 5 meters at maturity and with canopy coverage of more than 30% except in high altitude areas. Include forests in islands and Permanent Reserved Forests (PRFs) under Sustainable Forest Management but exclude water bodies such as natural or man-made lakes, major rivers and land dominated for agriculture and urban purposes.'

WRI assumes "trees" as forests and defined it as 'all vegetation taller than 5m in height, and may take the form of natural forests or plantations across a range of canopy densities'(Hansen et.al [7]) which may include agricultural plantation such as oil palm. Through their Global Forest Watch online system they have managed to produce statistics of "forest" cover loss for every state in Peninsular Malaysia beginning from the year 2001 to 2014. The data has been improved for the year 2013 and 2014 where they have succeeded in deducting non-forest tree plantation areas through their recent modification on the geospatial analysis.

Meanwhile WWF performed geospatial analysis on forest cover loss in Malaysia for the year 2001 to 2015(January to June) where they defined forest cover based on the pixel values of the processed MODIS images used.Values of 0 to 40 are interpreted as forests, while values of 41 to the maximum value of 255 are considered as deforestation[9].

Permanent Reserved Forest (PRF) is defined as 'any land constituted or deemed to have been constituted a permanent reserved forest under the National Forestry Act, 1984'[6]. A PRF is basically a forest, but may be a land without forest cover and legally gazetted administratively as one, while a land with forest cover may not be a PRF, as in the case of the Taman Negara and Krau Game Reserve.

## 3.Methodology

The comparing analysis with FDPM's official data and research geospatial data is made exclusively based on the area size statistics provided by WRI and WWF.

### *3.1 Forestry Department Peninsular Malaysia*

FDPM uses an integration of remote sensing and Geographical Information System (GIS) procedures to accomplish the task. Software used are ERDAS Imagine, ArcGIS and ArcView 3.x. For 2010 to 2014, SPOT 5 pan-sharpened 2.5 m spatial resolution satellite images obtained from Remote Sensing Agency Malaysia (ARSM) covering 68 scenes for Peninsular Malaysia were used (with the least cloud cover (less than 20% cloud cover). Whenever needed, additional ground control points (GCP) were added to improve the accurate positioning of the images on the actual map during geo-referencing[8]. The type of images were replaced by Landsat 8 and SPOT 6/7 for forest cover mapping beginning the year 2015. Initial Unsupervised classification (UC) was conducted on several imagery scenes. Each classes were identified using relevant GIS layers and ground-truthing of vague spots before Supervised Classification (SC) was performed to improve the results. However the classification output of SC was only slightly better than that of UC. The SC raster output was converted to GIS shapefile vector format. The vector layer was then overlayed with the same imagery scene to check for classification inconsistencies and to enable correction/editing. Once again, relevant GIS layers were used for support and as reference during editing. The re-digitising and correcting exercise proved to be cumbersome tasks thus the exercise was abandoned and not duplicated for the remaining scenes. Ghorbani [4] found that visual interpretation still produce higher accuracy than digital image classification for Landsat TM and Google Earth images. Previously, FDPM has been using visual interpretation technique to extract vegetation features from Landsat TM images (FDPM [2]). Nevertheless, the elements for visual interpretation for SPOT 5 imagery remains the same – tone, colour,shape, size, pattern, texture, shadow, height /depth, location and association. This is supported by overlay analysis with GIS layers Land Use Map produced by the Department of Agriculture (DOA), National Forest Inventory Map and topography map to enable the early creation of the rough forest cover layer in vector shapefile format. On-screen digitising was conducted to delineate the forest feature (based on the forest cover definition used) with on and off comparison made to the other related layers (where relevant, the same delineated boundary of the other layer is used to maintain boundary consistency). The forest delineation was further re-classified to separate the four (4) main forest types; inland forest, peat swamp forest, mangrove forest and forest plantation, again referring to the related layers for guidance. The digitised data underwent the topology process in ArcGIS to eliminate data irregularities such as sliver polygons. Validation exercises were carried out for the Forest Cover geospatial data produced in the previous year through hands-on geospatial verification workshops the following year conducted with geospatial and field personnel of the 12 SFDs in attendance. Uncertain/vague/grey areas were marked and recorded. On the ground inspections with further aerial surveillance using helicopters on several areas were implemented to enhance accuracy. The verified data (through the officially signed acceptance letter of the respective SFDs) were to be endorsed for usage by FDPM. The verified data from each states were merged into one official Peninsular Malaysia forest cover geospatial map data. The methodology used is as shown in **Appendix A.** The forest cover geospatial mapping was conducted every two years starting from the year 2009 but shortened to annually beginning 2015. For the purpose of this comparison analysis , the FDPM forest cover loss figures during each period are divided into the number of years involved so that an average figure can be derived to represent a particular year size acreage.

### *3.2 World Resource Institute*

The forest cover loss data set for Peninsular Malaysia inserted in the Global Forest Watch online system by WRI for the year 2001 to 2014 was produced through collaboration efforts with organisations such as University of Maryland, United States Geological Survey (USGS),Google and NASA[12]. They are generated from processed and analysed Landsat 5, Landsat 7 and Landsat 8 images. The clear land surface observations in the satellite images were assembled and a supervised learning algorithm was applied to identify per pixel tree cover loss. The analysis method has been modified in numerous ways, including new data for target year, reprocessed data for the year 2011 and 2012, and improved modelling and calibration (Hansen et al.[7]). The modifications improved forest change detection for 2011-2014 including better detection of smallholder agriculture in tropical forests, selective loss and short cycle plantations [13]. Further explanation of the methodology used are as in http://earthenginepartners.appspot.com/science-2013-global-forest.

*3.3 World Wide Fund*

WWF commissioned the Netherland-based remote-sensing agency, SarVision to undertake the processing of MODIS satellite images, processed into 7-band annual cloud free composites at 250m resolution [11] for spatial analyses of deforestation in Malaysia. The analysis done by WWF for forest cover loss are for the periods between July 2001-June 2005,July 2005June 2010,July2010-June 2013 and July 2014-June 2015. The processing encompassed the following procedures: i) generation of MODIS data, ii) classification of forest cover, iii) selection of images with appropriate pixel values for deforestation analyses, and iv) forest cover index (FCI) and map validation. The technical details of each procedure are as given in **Appendix B**. WWF additionally implemented deforestation analysis according to the respective states and PRFs of Peninsular Malaysia. For the purpose of this comparison analysis, the WWF forest cover loss figures during each period are divided into the number of years involved so that an average size figure can be derived for each particular year. The period between July to June of each period are assumed as the period between January to December of each year.

## 4. Results & Discussion

*4.1 Forest cover loss 2001 to 2010*

Table 1 : Forest cover loss (in '000 hectares) 2001-2010.

| Source | Year ('000 hectares) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | Total |
| WRI | 169.4 | 179.1 | 77.0 | 156.1 | 180.7 | 144.6 | 167.3 | 120.5 | 224.3 | 190.1 | 1,609.1 |
| WWF | 264.9 | 264.9 | 264.9 | 264.9 | 264.9 | 104.2 | 104.2 | 104.2 | 104.2 | 104.2 | 1,845.5 |
| FDPM Annual Report [a] | 54.8 | 32.1 | 13.6 | 12.8 | -21.3 | -25.1 | 72.0 | -3.0 | -29.5 | 9.5 | 115.9 |

[a] Forest area loss.

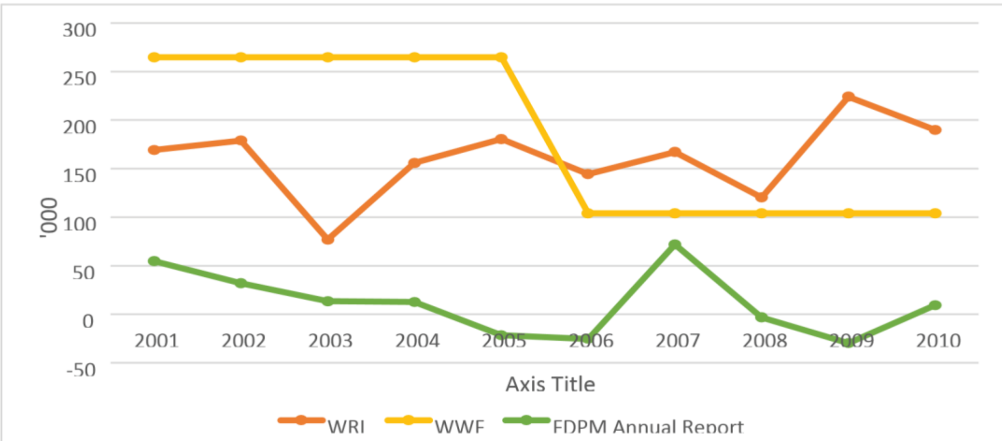


**Figure** 1 : Forest cover loss (in '000 hectares) 2001-2010.

Forest cover loss statistics based on “current year minus year before” calculations of forest area figures published in the FDPM Annual Reports as shown in Table 1 and Figure 1 are merely used as “partial” comparison of geospatial technology derivation by WRI and WWF versus conventional reporting by FDPM as it did not produce geospatial forest cover mapping data before the year 2010. The forest area published in the FDPM Annual Report is not based on satellite imagery interpretation but from conventional statistical reporting collected from the SFDs. The forest gain in 2005, 2006,2008 and 2009 reported are figures based on area additions through the inclusion of new areas gazetted as PRF and inclusion of forest areas identified through formal area applications received and ground surveys done by the SFDs on newly identified forest areas and areas not recognised as forest before(due to its immaturity or insufficient composition to identify it as one). Geospatial forest cover loss figures of WRI[12] and WWF showed higher forest cover loss of 1,388.4% and 1,592.3% respectively in comparison to FDPM’s conventional derived forest area loss of only 115,900ha between 2001 to 2010. WWF’s overall figure of 1,845,500 ha for the period is 14.7% higher than WRI’s figure of 1,609,100 ha. The period between 2001 to 2005 showed WWF’s period total size of 1,324.5 ha being 73.8% higher than WRI’s figure of only 762.3 ha. In contrast, for the period 2006 to 2010, WWF’s period total size of 521 ha was 38.5% lower when compared against WRI’s 846.8 ha.

*4.2 Forest cover loss 2011-2015*

Table 2 : Forest cover loss (in ‘000 hectares) 2011-2015.

| Source | Year (‘000 hectares) | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
| WRI | 203.3 | 255.1 | 88.8[b] | 200.7[b] | - | 747.9 |
| WWF | 139.0 | 139.0 | 139.0 | 74.5 | 74.5 | 566.0 |
| FDPM Geospatial | 94.2 | 94.2 | 56.2 | 56.2 | 72.7 | 373.5 |
| FDPM Annual Report [c] | 57.3 | 18.5 | -42.6 | 27.9 | - | 61.1 |

[b] Excluding agricultural tree plantations.
[c] Forest area loss.

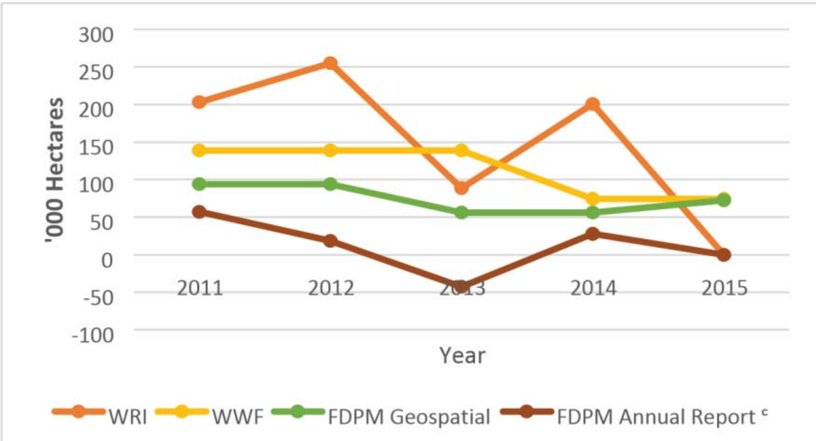


**Figure 2 :** Forest cover loss (in ‘000 hectares) 2011-2015.
Note : No data for WRI and FDPM Annual Report for the year 2015.
[c] Forest area loss.

The trend of forest cover loss analysis remained high in WRI[12] and WWF data as compared to FDPM’s dataset of both geospatial and annual report as illustrated in **Table 2** and **Figure 2**. WRI’s improved analysis

[13] where non-forest that includes agricultural tree crops are eliminated from the original forest cover loss figures for the year 2013 and 2014 still yield higher forest cover loss when compared to WWF(169.7%) and FDPM's geospatial(257.1%)figures for the year 2014. WWF and FDPM's geospatial results for the year 2014 and 2015 have smaller variations, where while WWF's data are larger in size, the percentages differ slightly at 24.5% for 2014 and 2.4% for 2015. FDPM have produced only bi-annual forest cover geospatial data for Peninsular Malaysia for 2009-2010,2011-2012 and 2013-2014 using SPOT 5 images due to the difficulty in obtaining cloud-free images over a one year period[8]. Since the FDPM's unavailability of SPOT 5 images from April, 2015, Landsat 8 images were mostly used for 2015 mapping exercise with several SPOT 6/7 images available for refinement. FDPM's geospatial forest cover loss figure is 5 times higher than FDPM's forest area loss data due to the difference between forest cover and forest area definitions where figure for the former used normally refers to only formal data. However the high variations between the two will be thoroughly investigated by FDPM to narrow the difference in the future.

### *4.3 Forest cover loss in PRFs 2011-2015*

Table 3 : Forest cover loss in PRFs (in '000 hectares) 2011-2015.

| Source | | | Year ('000 hectares) | | | |
|---|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 | Total |
| WWF | 35.3 | 35.3 | 35.3 | 29.5 | 29.5 [d] | 164.9 |
| FDPM Geospatial | 34.5 | 34.5 | 24.4 | 24.4 | 42.7 | 160.5 |

[d] Up to June 2015.

No analysis was conducted by WRI for this comparison. There are less variations between the figures of both entities where WWF's data was higher than FDPM's for most years except for 2013 and 2015 as indicated in **Table 3**. The different month period of both data to represent a particular year and the average figure used may be the reason for the variation shown in the year 2013. While WWF consistently applied the MODIS data, FDPM used Landsat 8 for 2015, replacing SPOT 5 which were used in previous forest cover mapping exercises. FDPM's geospatial data displayed higher figure compared to WWF's since FDPM's data was generated from available images dated throughout 2015 while WWF's 2015 actual image sources was from July 2014 to June 2015. The loss of forest cover within PRFs in a sizeable manner occurs when a large area is clear felled for the establishment/replanting of a forest plantation or other non-forest development such as for utilities/infrastructure constructions (e.g. dam, transmission line or highway/road network). The close figures between the two for 2011,2012 and 2014 indicated that images with low spatial resolution used by WWF can produce accurate results with the correct digital image processing technique as compared to visual interpretation using higher spatial resolution images. The analysis focusing on smaller specified areas (such as the PRF) may also be a contributing factor.

## 5.Conclusion

Conserving and protecting forest cover has never been so important as in these past few decades in order to sustain social, economic and environmental stability of a country. Malaysia has pledged to maintain at least 50% of its forest intact during the Rio Summit and the pledge has been renewed from time to time (the latest by the Malaysian Prime Minister during the opening ceremony of the Inter-governmental Plenary Session of Biodiversity and Ecosystem Services (IPBES 2016) in Kuala Lumpur on the 22nd February 2016)[14]. According to the Global Forest Resources Assessment Report 2015 [1] , Malaysia still has 68% of its land covered with forests where most of them are distributed in Sabah and Sarawak. The use of geospatial technology, especially remote sensing, has made forest cover monitoring possible in producing a better depiction of the status of the resource. The challenge in having cloud cover free images can be overcome in the future, through the use of radar, airplanes or drones mounted with appropriate sensors and cameras to complement the cloud-covered, "cataract" scenes. Forests are dynamic vegetation liable to grow back over time if left undisturbed thus forest gain is possible besides reforestation and afforestation. A forest plantation is managed in a way that it will be 100% felled at maturity and thus the forest cover will indicate a sizeable cleared area if an image taken on that date is used during analysis. This is in contrast to the "before" image of the same area with the forest or forest plantation still standing. Thus the date of the images used influenced the forest cover loss size output of the year in analysis. The use of different image from different sensor with different spatial resolution are additional factors to consider. Higher spatial resolution images is assumed to produce more accurate delineation. As FDPM has revert to using Landsat 8 beginning 2015 with a lower spatial resolution of 15 m as compared to using SPOT 5 before this, the accuracy consistency may no longer be maintained. However SarVision's (on behalf of WWF) use of MODIS images with lower spatial resolution of 250 m [11] but using different processing and analysis method to generate size figures with less variation in comparison to FDPM for the total period 2011-2015 for PRFs need to be explored further to determine its merit. These are the few issues which need to be resolved before the forest cover data through remote sensing interpretation and GIS can be used and published by FDPM in addition to the existing forest area statistic data in the near future.

## 6.References

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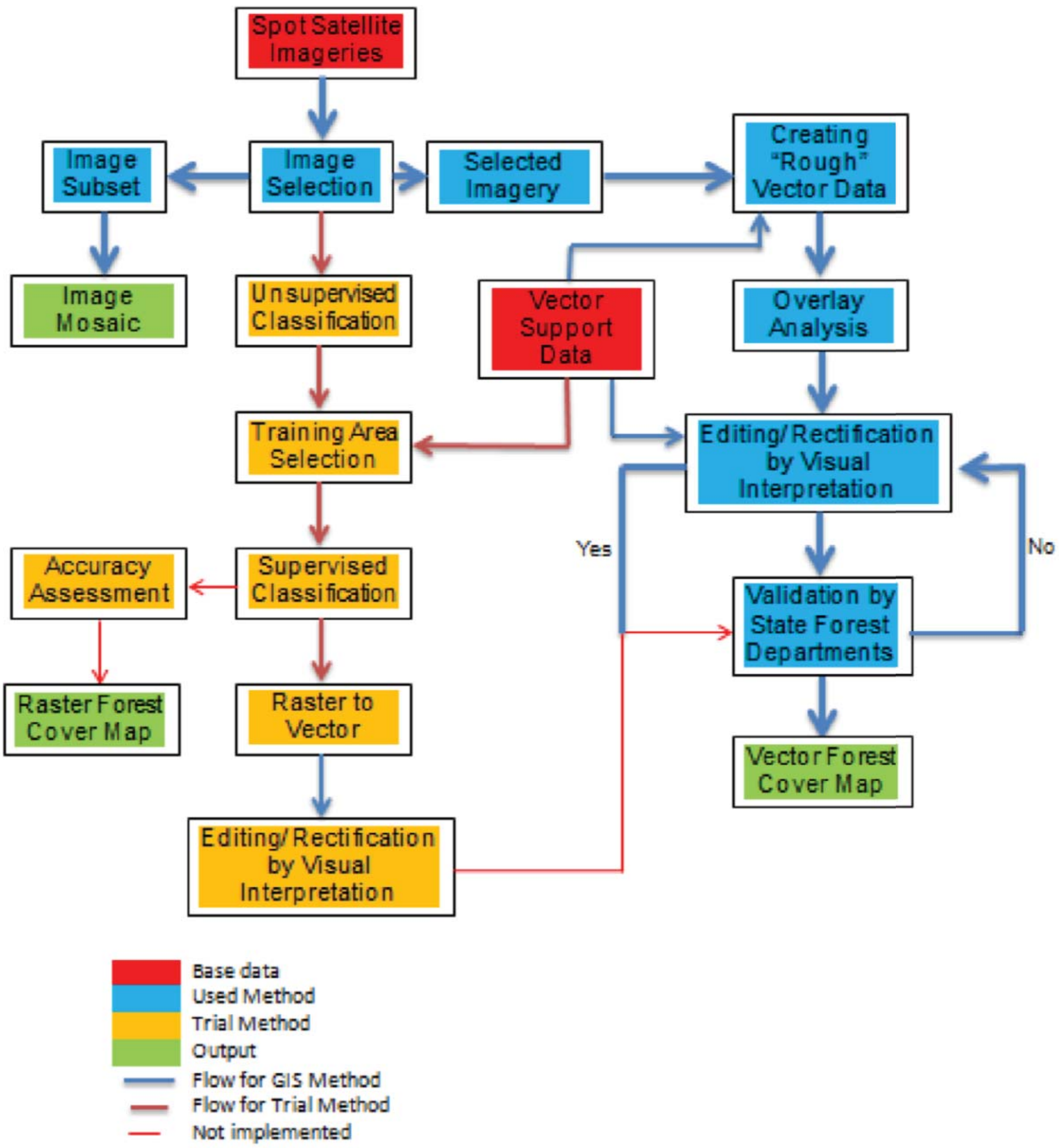
[14] Witnessed by the author through official attendance on 22 February 2016.

**Appendix A Forest cover mapping methodology for FDPM**



## Appendix B Forest cover mapping methodology for WWF

**Generation of MODIS satellite images –** Based on published science-based materials, SarVision developed a fully automated system that received the MODIS daily surface reflectance products from Aqua and Terra satellites as data inputs. Calibration, radiometric, geometric, and topographic terrain corrections were performed on the automated satellite images. Computer analyses of automated cloud and haze removal and annual compositing techniques were used to select images with the best pixels, generating the MODIS annual composite images with the minimal amount of cloud cover as required. The targeted cloud cover was 0%. All daily images were processed into
7-band annual cloud-free composites at 250m resolution, and analyzed with the relevant statistics.

**Classification of forest cover—** Forest covers were classified based on two MODIS yearly cloud free images for each period of change, and where applicable, images of two consecutive years were used. A forest index was then calculated for each image using the threshold of the spectral information based on an empirical relationship established by SarVision using knowledge of the land-use practice in the region. The resulting maps gave an indication of the forest quality. A map of forest cover loss index was also generated to show the extent of deforestation or forest degradation. The final deforestation index was dependent on both the quality of the original vegetation in year 0, and the absolute difference with year 1. Small corrections were performed on the indices, where applicable, upon manual inspection.

**Selection of images with appropriate pixel values for deforestation analysis –** In analyzing the MODIS images for forest cover index, pixel values of 1 – 255 denoted the increasing level of detected forest cover loss, and the pixel value would become zero when no forest cover loss was detected. Images with pixel values of 1 – 40 (loss of forest cover below 15%) were indicative of slight or no significant loss of forest cover or they may be related to seasonal changes in vegetation. In comparison, images with pixel values of 41 to 255 (loss of forest cover exceeding 15%) were indicative of substantial deforestation, and these changes in forest cover are not likely to be reversible in the future. Hence, only MODIS images of pixel values exceeding 40 were used to assess the areas of deforestation, in which spatial analyses were performed using the Tabulate Area calculation for MODIS forest cover index from year 2001 to 2015.

**Forest Cover Index (FCI) and FCI map validation –** SarVision validated the FCI map as close to the reference date of 30$^{th}$ June 2013 as possible; the FCI map was produced against Very High Resolution (VHR) data available on GoogleEarth. The FCI map for Peninsular Malaysia showed an overall accuracy of 96% and all reliability figures were well above 90% accuracy, allowing us to discriminate dense, tropical forest from other land-cover or land-use types.