Available online at *gisws.media.osaka-cu.ac.jp/gisideas16/*

GIS-IDEAS 2018

International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)

Multi-sensor remote sensing for national monitoring of forest changes – A case study of Hoa Binh province

Le Thi Khanh Hoa[1], Pham Khanh Chi, Tran Hung

GeoViet Consulting Co., Ltd., Hanoi, Vietnam,

Abstract

Vietnam recently completed the National Forest Inventory and Statistics (NFIS) program 2013 - 2016 with the comprehensive forest resources database being managed by the Forest Protection Department (FPD). It is now imperative for FPD to maintain up-to-date information on forest-cover change in support of government strategies on forest protection and development at national and local scales. This paper aims at developing a workable methodology to use time-series of readily available multi-sensor satellite images in support of FPD's forest change monitoring. Several internationally-recognized forest classification and change detection methods – such as K-means for MODIS NDVI time-series data or NBR, Delta-NBR based methods for Landsat-8 and Sentinel-2A images - are adopted for monitoring the annual changes of forest covers in Hoa Binh province during 2015 - 2017. As results, this case study shows that a combination of described methods on multi-sensor data and GIS can produce enhanced forest cover and forest change maps over the years. A comparison between remote sensing derived forest classification and statistics with to the forest inventoried maps and official reports by the provincial authority is then, conducted for reliability analysis for various forest types and for discussing remain issues of the proposed methodology. With these preliminary results, the paper demonstrates that remote sensing methods can be valuable in effective monitoring forest changes, that can be further developed into a set of practical tools in support of FPD for its operations such as regular reporting of forest cover statistics at national and local levels.

Keywords: Forest changes, forest inventory, MODIS, Landsat, Sentinel-2, NDVI, K-means, Delta-NBR

1. Introduction

In 2017, the forest covers 41.45% of total natural land of Vietnam (VAF - *http://tongcuclamnghiep.gov.vn)* as results of great combined effort of the government and people in forest protection and development at national and local scales. As deforestation and forest degradation are often reported from place to place, sometime quite rapidly, accurate inventory and continuously monitoring of forest resources are required for effective planning, management and protection of these important resources. Traditionally, the Forest Protection Department (FPD) under VAF is annually combining forest cover data from its local agencies at provincial and district levels, which is mostly manual and rather tedious process. As the national forest resources database standardized and managed in the computerized Forest Resources Management System (FRMS) since 2016, the FPD can now gradually streamline the data collection, transmission and aggregation processes. Still, the forest inventoried maps are updated locally based on self-reporting by forest-land owners and limited field data, which are often inaccurate and inconsistent from locations to location. There are discrepancies in provincial annual reports by provinces, calling for independent cross-checking mechanisms.

[1] *Corresponding author: khanhhoa.geoviet@gmail.com*

Remote sensing of the Earth from satellites has, over the years, made great progress in monitoring land-cover, especially forest cover. Terra-i (http://terra-i.org/) - a near real time monitoring system – can provide maps of natural vegetation loss detection for every 16 days since 2004 based on automated K-means classification of MODIS time series data, while the Regional Forest Observatory in Continental South-East Asia (RFO-SEA - http://rfo-sea.org/mapviewer/) provides annual tree cover loss since 2001 based on analyzing Delta-NBR of Landsat and Sentinel images. Followed well-tested methods of those two systems, this paper focuses on developing a combined procedures of using available remote sensing data to update and monitor forest cover changes in Hoa Binh province during 2015-2017 with a look to support of FPD's mandate reporting while supervising forest cover statistics from local levels.

2. Data and methodology

2.1. Study area and data used

Neighboring Hanoi to the west, Hoa Binh is a mountainous province located in the Vietnam's Northwest region with a total area of 4.609 km^2 (Figure 1). Mountains with mostly forest at elevation of 600-700m AMSL and slope of 30-35^0 are in the northwest, covering 46% of total province area, while the remaining area at elevation of 100-200m with mixed agriculture. Covering 51.19% of the total province area in 2015 (or 234.909 ha), forest is the important resource providing livelihood for about 808,000 people, mostly indigenous people of Muong, Thai, Dao, Tay, H'Mong... With economic growth, the forest land is under pressure to be converted to other land uses such as agro-forestry, farming, urban / industrial and hydropower development.

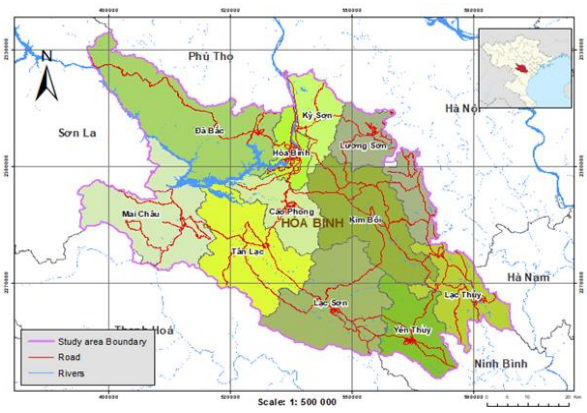


Fig. 1. Administrative map of Hoa Binh province

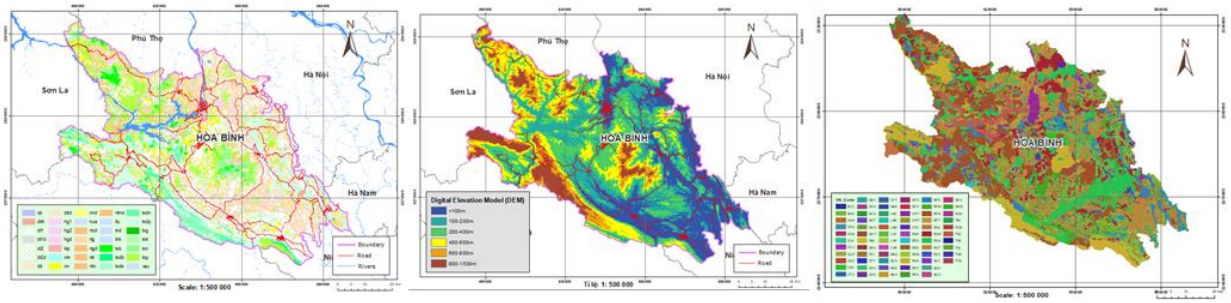
A set of satellite data scenes fully covering Hoa Binh province during 2015–2017 was collected for the study, including 23 images of 16-day cloud-free composites of MODIS/Terra Vegetation Indices for whole year of 2015 at 250m resolution; 2 Landsat-8 OLI scenes (dated 07 April 2015 and 15 June 2017), and a Sentinel-2A MSI image (dated 20 December 2017) – see details in Table 1. The MODIS sensors on Terra or Aqua satellites provide daily multispectral images, from which NASA produce a number of land products including standard MOD13Q1 images for land cover monitoring (https://modis.gsfc.nasa.gov/data/). Provided by USGS, Landsat images have been used for longtime in monitoring the Earth surface and with new generation of Landsat-8 since 2013, this readily-available dataset provides a much better global coverage as well as increased spectral and radiometric capabilities in Earth resources measurements (http://earthexplorer.usgs.gov/). Developed by ESA since 2015, Sentinel data (https://sentinel.esa.int/web/sentinel/home) provide a good complement and continuity for the current SPOT and LANDSAT data with even better spatial resolution (around 10m), larger image swath and shorter revisit time. As both Sentinel-2 and Landsat-8 cover similar spectral range, with identical SWIR bands for canopy disturbance monitoring (see Figure 3), these two data sets are comparable and could complement each other in this study.

Table 1. Satellite data collected for the study

Sensor/ product name	**Processing level**	**Acquisition Date**	**Entity ID/ Product uri**
MODIS/Terra Vegetation Indices 16-Day	Level-3	2015	23 mosaic images for Julian days of 001 – 353/2015
Landsat-8 OLI/TIRS	Level-1T	2015-04-07	LC08_L1TP_127046_20150701_20170407_01_T1
		2017-06-15	LC08_L1TP_127046_20170604_20170615_01_T1
Sentinel-2A MSI	Level-1C	2017-12-20	4 scenes

Ancillary data were also collected to assist image classification, post-classification, change detection and forest cover and forest change statistics summarization, including: DEM, topographical features, administrative boundaries, existing land use map and official (FPD) forest inventoried map scaled 1:25.000 for 2015 (Figure 2).

Fig. 2. Hoa Binh Forest Inventoried Map 2015 (FPD) (a), DEM ASTER (30x30m) (b), Land Use Map 2015 (c).



a) b) c)

2.2. Processing and analysis methodology

After obtaining satellite data, different image processing and analysis techniques were applied in 3 steps: (1) pre-processing & calculation of indices; (2) classification; and (3) change detection & statistical summation (Figure 3). ENVI 5.4 and ArcGIS 10.4 were used for this study. The standard MODIS MOD13Q1 products in ISIN projection were re-projected to VN2000 coordinate system and then, layer stacked to create a 23-band NDVI image for 2015. This NDVI time-series image was used for K-means classification in order to create land cover map 2015. As the focus of the study is on forest cover monitoring as a potential cross-checking mechanism to regular reports from local levels, the classification is into 5 categories of evergreen forest, mixed forest, other vegetation, other land and water bodies. The classified map was combined with existing land use map 2015, DEM and Landsat-derived NBR image for post-classification processing in order to remove uncertainty and improve classification accuracy. The resulted forest cover map was then, overlaid on administrative map for calculation of 2015 forest statistics by district.

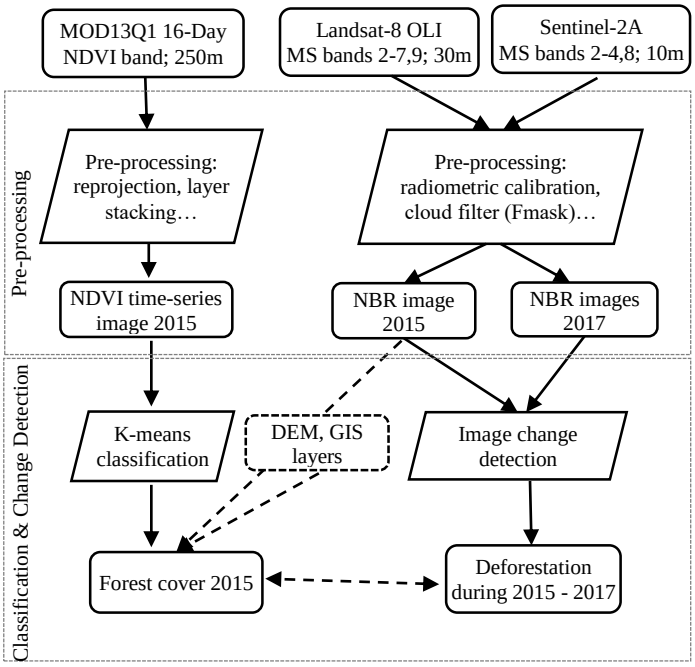


Fig. 3. Flowchart of the data and methodology used in the study

The collected Landsat-8 and Sentinel-2A data were pre-processed including radiometric calibration with QUAC model, geometric correction / georeferencing to the standard basemaps in VN2000 coordinate system, cloud filter and gap filling and resampled to 30-m pixel size. The processed images were used to calculate Normalized Burned Ratio (NBR) indices for 2015, 2017 based on following equation: NBR = (NIR - SWIR2) / (NIR + SWIR2).

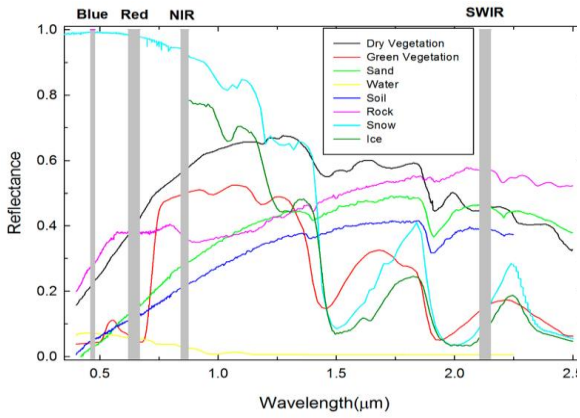


Fig. 4. Typical spectral reflectance curves for vegetation, ice, snow, soil, water, and sand in the visible to short-wave infrared (SWIR) range (Xin-peng Tian et al., 2016).

As Figure 4 shows, both NIR and SWIR bands are sensitive to vegetation cover with canopy moisture more relates to reflectance in the SWIR region. Cibula et al., (1992) indicated that dry leaf biomass has a similar reflectance in NIR as in SWIR, whereas a healthy leaf has lower reflectance in SWIR. Additional advantage is that NBR are insensitive to cloud shadows, since they appear to lower the reflectance in both NIR and SWIR equally. As such, NBR is used not only for monitoring of forest burned areas but also for

differentiating bare land, built-up areas from forest and for selective logging detection as it is perceived to be more sensitive to disturbance events (Schneibel et al., 2017; Shimizu et al., 2017). In this study, the NBR image computed from Landsat-8 in 2015 was used to improve classified forest map (see details below). Furthermore, as recognized canopy disturbance indicator, the Delta-NBR 2015-2017 computed as the difference of NBRs from Landsat-8 acquired in 2015 & 2017 (Delta-NBR = $NBR_{2017} - NBR_{2015}$) was used for forest change detection, both for forest loss and for forest restoration in Hoa Binh province.

3. **Results and Discussion**

3.1. Forest cover classification results

Figure 5 shows the classification result of MODIS NDVI time-series 2015 for Hoa Binh province using K-means classification and post-classification filtering. The 5-categories classified map of evergreen forest, mixed forest, other vegetation, other land and water bodies was further cross-checked with the existing land use map 2015 in order to identify and further separate mixed-classified areas. It was found that the evergreen and mixed forest areas are quite well separated, while degraded forest and young plantation forest are often confused with other vegetation or agricultural land – all under the broad other vegetation category. DEM data was then used to further separate those confused categories (e.g., plantation forest from agriculture land or other vegetation) as a detailed screening of forest cover throughout Hoa Binh province found that more than 71% of forest distributed in the area with elevation of 200m AMSL and more. Further, Landsat-derived NBR image is used to separate bareland and water bodies from vegetated areas based on a threshold value of NBR<=0.25. Figure 6 shows the aggregated forest cover map with only forest / non-forest categories as a result of combined DEM and NBR information into the classification / post-classification process. Accuracy assessment based on 24 samples of reference data from ground-truthing and high-resolution images on Google Earth shows good overall accuracy and kappa value of 97% & 0.95 respectively in the aggregated forest /non-forest classification.

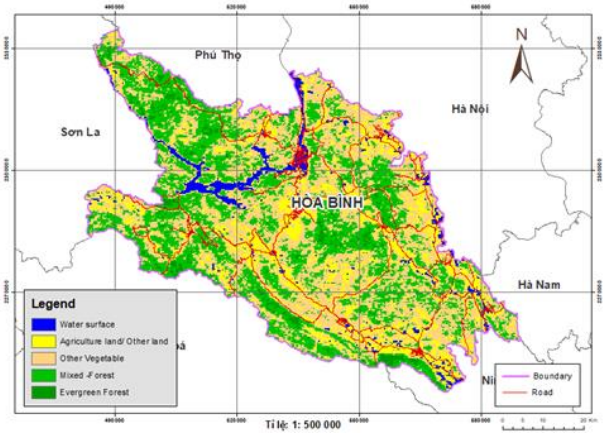


Fig. 5. Land cover K-means classification result from MODIS NDVI time-series image

Fig. 6. Forest cover classification result combined with DEM and Landsat-derived NBR Image 2015

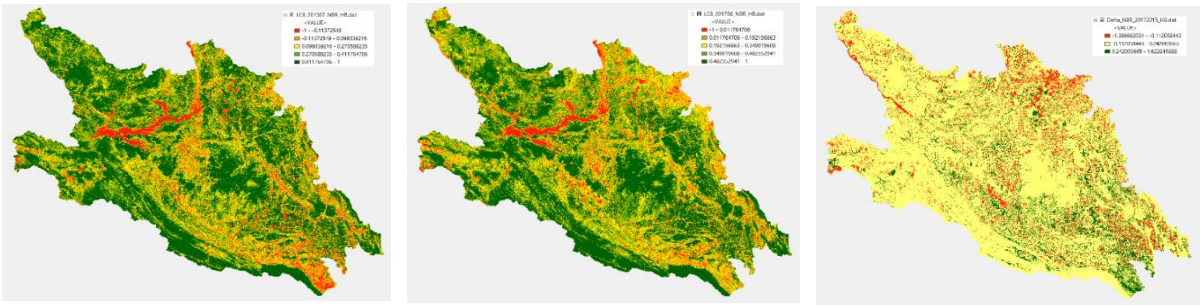
Table 2. Forest cover areas in hectares by district in 2015 as derived from remote sensing as compared to the official FPD report

No.	District	Statistics from forest map (FPD -2015)	Statistics from forest cover map - K-means classification (2015)	No.	District	Statistics from forest map (FPD -2015)	Statistics from forest cover map - K-means classification (2015)
1	Hoa Binh	6,533	5,131	7	Tan Lac	25,353	26,310
2	Da Bac	49,759	53,428	8	Mai Chau	39,193	39,359
3	Ky Son	8,041	7,568	9	Lac Son	31,494	24,402
4	Luong Son	11,692	8,057	10	Yen Thuy	11,032	7,598
5	Kim Boi	27,335	28,809	11	Lac Thuy	14,183	7,711
6	Cao Phong	10,294	11,578	**Total province**		**234,909**	**219,951**

Statistical summation of the final classified map shows the total forest area for whole Hoa Binh province is of 219,951 ha, which is in a good match to the value of 234,909 ha in the FPD official report. Table 2 shows detailed forest cover statistics by district in Hoa Binh province as compared to the statistics extracted from the FPD forest inventoried map 2015.

3.2. Deforestation in Hoa Binh province during 2015-2017

From the Landsat-derived NBR images of 2015 and 2017, the Delta-NBR 2015-2017 image was computed (Figure 7), which then used for forest change detection based on simple threshold method. Based on local knowledge and reported forest changes samples, a threshold value of Delta-NBR < -0.1 was defined for areas of forest loss (converted into bareland or special-use land with non-vegetation) and Delta-NBR >= 0.25 for areas of forest restoration / regrowth…



a) b) c)

Fig. 7. Landsat-derived NBR image 2015 (a) & 2017(b) & Delta-NBR 2015-2017 image (c)

Figure 8 shows the resulted forest cover change map during 2015-2017, where areas of forest loss are in red and areas of forest restoration in green. Based on the FPD definition of forest units, small areas of less than 0.5 ha were filtered out. Overall, during those 2 years, there's observed considerable forest changes in Hoa Binh province, both in terms of deforestation (about 28,721 ha)) and reforestation / restoration (23,840 ha). Spatially, those changes are varying from district to district as shown by forest change statistics summarized by district (Table 3). Forest loss areas found largest in Luong Son and Ky Son districts followed by Kim Boi, Lac Thuy and Da Bac districts while forest restoration areas most found in Lac Son, Kim Boi, Yen Thuy and Lac Thuy districts. These summarized statistics are broadly indicating spatial distribution of forest changes in Hoa Binh province, which can be used for zoning of focus areas for further investigation on-field or using very-high resolution satellite data by local forest rangers.

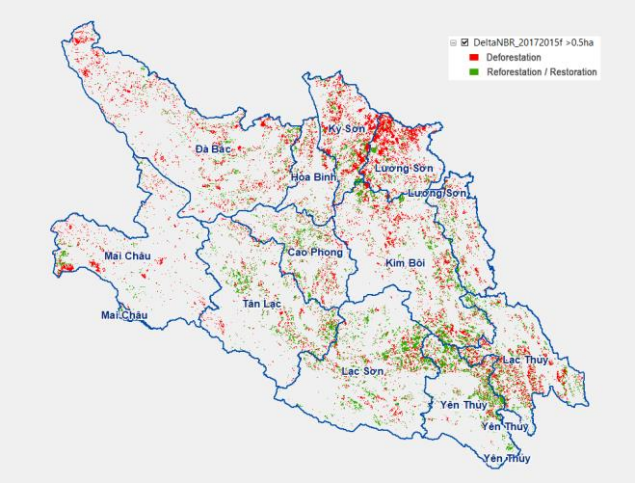


Fig. 8. Forest cover change map during 2015-2017 based on Delta-NBR thresholds

Table 3. Forest cover change statistics in hectares by district during 2015-2017

No.	District	Forest loss areas	Forest restoration area	No.	District	Forest loss areas	Forest restoration area
1	Cao Phong	1,361	1,619	7	Lac Thủy	2,926	2,705
2	Da Bac	4,541	2,066	8	Luong Son	4,870	1,772
3	Hoa Binh city	933	597	9	Mai Chau	1,791	773
4	Kim Boi	3,590	3,687	10	Tan Lac	1,789	2,488
5	Ky Son	3,509	1,343	11	Yen Thuy	1,264	2,784
6	Lac Son	2,148	4,005		**Total province**	**28,721**	**23,840**

In order to find out which forest types (by condition or status) were experienced most changes in Hoa Binh province during 2015-2017, the FPD inventoried map 2015 was used to select out non-forest areas and then, overlay with the Delta-NBR derived forest change map 2015-2017. Table 4 shows that the among 11 main forest conditions (states) in Hoa Binh province, the *broad-leaves evergreen forest* has the most deforested area of 3,279 ha, followed by the *rocky mountain forest* of 772 ha while 11,967 ha of plantation forest loss may be attributed to normal logging. However, the detected forest restoration areas need to be further verified through field investigation in order to identify its natures for forest management purposes, such as regeneration of old forest, new plantation or simple regrowth…

Table 4. Forest cover change statistics in hectares during 2015-2017 as derived from remote sensing grouped by forest conditions inventoried in 2015 by FPD

No	Forest Conditions	Forest loss area	Forest restoration area	No	Forest Conditions	Forest loss area	Forest restoration area
1	Broad-leaves evergreen forest	3,279	2,074	7	Plantation forest	11,967	6,374
2	Needle-leave forest	1	5	8	Plantation (not yet forest)	4,316	7,117
3	Rocky mountain forest	772	421	9	Agriculture land	2,492	2,359
4	Mixed (wood-bamboo) forest	529	220	10	Shrub-land	4,497	4,562
5	Bamboo forest	73	60	11	Other land	633	499
6	Regeneration forest	161	149		**Total province**	**28,721**	**23,840**

4. Conclusions and Future Work

This study shows that K-means classification method for MODIS NDVI time series combined with other multi-sensor satellite data, DEM and GIS data provides good accuracy in forest mapping in Hoa Binh province in 2015. In addition, using NBR and Delta-NBR indices computed from Landsat and Sentinel data with simple thresholds provides an effective mapping of forest cover changes. The forest cover change statistics during 2015-2017 derived in this study when comparing with the FPD report can delineate focus areas in need of additional cross-check and field investigation. With increasingly freely available multi-sensor and multi-date satellite data, the image analysis flow developed in this study has a good potential in practical forest cover update and change detection that support FPD's cross-checking of local reports on forest inventories. Together with NDVI-based methods and routines developed in Pham Khanh Chi, *et al.* (2016), the authors will continue to (1) improve forest mapping accuracy and (2) develop semi-automated routines in a WebGIS-based application aiming at supporting FPD's mandate in accurate and timely monitoring of forest resources in Vietnam.

References

Bernstein, L. S., X. Jin, B. Gregor, and S. Adler-Golden. "Quick Atmospheric Correction Code: Algorithm Description and Recent Upgrades." Optical Engineering 51, No. 11 (2012): 111719-1 to 111719-11.

Dainius Masiliūnas, "Evaluating the potential of Sentinel-2 and Landsat image time series for detecting selective logging in the Amazon", M.S thesis, Wageningen University and Research Centre, The Netherlands, 2017. Available: http://library.wur.nl/WebQuery/titel/2223891.

Key, C. H., Benson, N., Ohlen, D., Howard, S. M., and Zhu, Z. (2002). The normalized burn ratio and relationships to burn severity: ecology, remote sensing and implementation. In Ninth biennial remote sensing applications conference, Apr 8–12, San Diego, CA.

Pham Khanh Chi, Le Thi Khanh Hoa, Tran Hung (2016). Using Multi-sensor Remote Sensing and WebGIS to monitor Deforestation in Dak Nong Province during 2010-2016. Proceedings of the International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS), Hanoi 2016.

Shimizu, K., Ponce-Hernandez, R., Ahmed, O. S., Ota, T., Win, Z. C., Mizoue, N., and Yoshida, S. (2017). Using Landsat time series imagery to detect forest disturbance in selectively logged tropical forests in Myanmar. Canadian Journal of Forest Research, 47(3):289–296.

Souza, C. M., Roberts, D. A., and Cochrane, M. A. (2005). Combining spectral and spatial information to map canopy damage from selective logging and forest fires. Remote Sensing of Environment, 98(2):329–343.

SUHET (2015). Sentinel-2 user handbook. Revision 2.

Xin-peng Tian, Lin Sun (2016). Retrieval of aerosol optical depth over Arid Areas from MODIS data. Atmosphere, 7(10) 134.