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Using Multi-sensor Remote Sensing and WebGIS to monitor Deforestation in Dak Nong Province during 2010-2016

Pham Khanh Chi*, Le Thi Khanh Hoa, Tran Hung

GeoViet Consulting Co., Ltd., Hanoi, Vietnam

Abstract

Deforestation and forest degradation are reported becoming more and more serious problems for Vietnam's central highland provinces in recent years. This paper aims at monitoring deforestation in the Dak Nong province during 2010 – 2016 based on integration of remote sensing technologies and GIS. Using NDVI-based image classification of multi-date, multi-sensor satellite images of Landsat-7 & 8 and Sentinel-2A with ground sampling data, annual forest cover maps are accurately derived, which are then combined to generate forest cover change maps. Integrated into the GIS forest database, the change analysis identified total deforestation area of 31,219 ha during 2010 – 2016, due to illegal timber cutting, forest fire and conversion to agricultural land or plantation… The paper then demonstrates how the results of forest change analysis can be readily integrate into a Web-based GIS forest database, that can support the provincial authority in detailed forest management and timely forest protection.

Keywords: Landsat, Sentinel-2, Deforestation, NDVI, Image Classification, Change Detection, WebGIS

1. Introduction

The forest cover in the central highland region is around 46.08% in 2015 based on the official report by the Vietnam Administration of Forestry (VAF). The region is well-known for its dense primary forest and high biodiversity as traditional livelihood for more than 5.5 million, mostly ethnic minority, special-cultured population. In recent years, deforestation and forest degradation are reported becoming more and more serious problems for the region as forest is being illegally cut or forest land is uncontrollably converted to other uses. Accurate inventory and continuously monitoring of forest resources are required for effective planning, management and protection of these important resources. The National Forest Inventory and Statistics (NFIS) program carried out province by province by VAF since 2011 is expected to provide complete forest resource data for the whole country by the end of 2016. Satellite data (e.g., SPOT 5, SPOT 6 and VNREDSat-1 images) are being used in combination with field works for the mapping purpose. However, the use of remote sensing data is reportedly still limited to visual interpretation and manual digitization with only few experimentation in digital classification. For regular monitoring of forest resources, the existing inventory techniques take long time, are quite tedious and clearly ineffective, which calls for applications of advanced remote sensing and GIS techniques in an integration chain with a look toward an operational 'automatic' forest monitoring system. In line with this practical need, this paper focuses on researching simple digital image classification techniques that can be applied with readily-available multi-sensor data of Landsat and Sentinel-2A to create accurate deforestation maps for Dak Nong province during 2010 – 2016, which then integrated into a GIS forest database for potentially operational forest watch.

* Corresponding author. Tel.: +84 901 776685.
E-mail address: chi.geoviet@gmail.com.

2. Data and methodology

2.1. Study area and data

Located in the Central Highland region of Viet Nam, the study area covers whole Dak Nong province with a total area of 651,561 ha (Figure 1). This is a hilly province with average and maximum elevation of 600-700m and 1,982m AMSL respectively. Covering 39.1% of the total province area in 2015, forest is the most important resource providing livelihood for about 600,000 people. The Dak Nong forest (mostly dense natural forest - about 84.39% of total forest cover) can be characterized by the semi-deciduous 'Khop' forest in the Northwest districts of Cu Jut and Dak Mil and the evergreen forest with plantation concentrated in the remaining districts. With economic growth, the forest cover is under pressure to be converted to other land uses such as agro-forestry, cultivation, urban and industrial development.

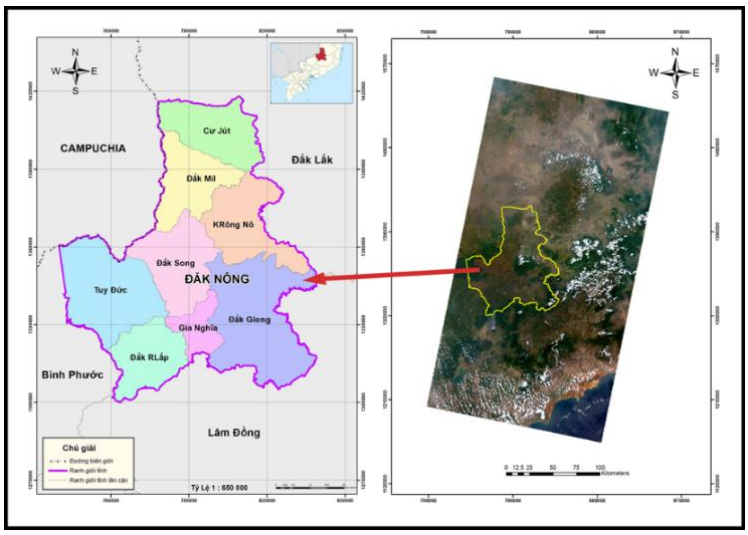

Fig. 1. Administrative map and satellite image of the Dak Nong province

Table 1. Satellite data collected for the study

Sensor name	Processing level	Acquisition Date	Entity ID/ Product uri
Landsat-7 ETM+	Level-1T	2010-03-16	LE71240512010075EDC00
		2010-03-16	LE71240522010075EDC00
Landsat-8 OLI/TIRS	Level-1T	2015-02-18	LC81240512015049LGN00
		2015-02-18	LC81240522015049LGN00
		2016-04-25	LC81240512016116LGN00
		2016-04-25	LC81240522016116LGN00
Sentinel-2A MSI	Level-1C	2016-03-04	380_2016-03-07T11_03

A set of satellite data scenes fully covering Dak Nong province during 2010–2016 was collected for the study, including 2 Landsat-7 ETM+ scenes (dated 16 March 2010), 4 Landsat-8 OLI images (dated 18 February 2015 and 25 April 2016), and a Sentinel-2A MSI image (dated 4 March 2016) – see details in Table 1. 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 (https://scihub.copernicus.eu/dhus/#/home), Sentinel-2A data provide a good supplement 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-2A and Landsat-8 cover spectral range between 440 and 2,300 nm (Table 2), these two data sets are comparable and could complement each other in this study (ESA, 2015 & USGS, 2015). In addition, base maps, existing forest maps with SPOT-image maps and related reports for the area were collected for analytical process in an integrated GIS forest database.

Table 2. Landsat-7 ETM+, Landsat-8 OLI/TIRS and Sentinel-2A MSI comparison

Landsat-7 ETM+			**Landat-8 OLI/TIRS**			**Sentinel-2A MSI**		
Band	Wavelength (μm)	Resolution (m)	Band	Wavelength (μm)	Resolution (m)	Band	Wavelength (μm)	Resolution (m)
-	-	-	B1-Coastal aerosol	0.433-0.453	30	B1-Blue	0.433-0.453	60
B1-Blue	**0.45-0.52**	**30**	**B2-Blue**	**0.450-0.515**	**30**	**B2-Blue**	**0.458-0.523**	**10**
B2-Green	**0.52-0.60**	**30**	**B3-Green**	**0.525-0.600**	**30**	**B3-Green**	**0.543-0.578**	**10**
B3-Red	**0.63-0.69**	**30**	**B4-Red**	**0.630-0.680**	**30**	**B4-Red**	**0.650-0.680**	**10**
B4-NIR	**0.77-0.90**	**30**	**B5-NIR**	**0.845-0.885**	**30**	**B8-NIR**	**0.785-0.900**	**10**
			-	-	-	B5-Red Edge	0.698-0.713	20
-	-	-	-	-	-	B6-Red Edge	0.733-0.748	20
-	-	-	-	-	-	B7-Red Edge	0.765-0.785	20
-	-	-	-	-	-	B8A-NIR	0.855-0.875	20
-	-	-	-	-	-	B9-Water vapor	0.930-0.950	60
-	-	-	B9-Cirrus	1.360-1.390	30	B10-Cirrus	1.365-1.385	60
B5-SWIR 1	**1.55-1.75**	**30**	**B6-SWIR 1**	**1.560-1.660**	**30**	B11-SWIR 1	1.565-1.655	20

Landsat-7 ETM+			**Landat-8 OLI/TIRS**			**Sentinel-2A MSI**		
Band	Wavelength (μm)	Resolution (m)	Band	Wavelength (μm)	Resolution (m)	Band	Wavelength (μm)	Resolution (m)
B7-SWIR 2	**2.09-2.35**	**30**	**B7-SWIR 2**	**2.100-2.300**	**30**	B12-SWIR 2	2.100-2.280	20
B8-PAN	0.52-0.90	15	B8-PAN	0.500-0.680	15	-	-	-
B6-TIR	10.40-12.50	60 (30)	B10-TIR 1	10.3-11.3	100 (30)	-	-	-
			B11-TIR 2	11.5-12.5	100 (30)	-	-	-
Launch: April 1999 - present			Launch: March 2013 - present			Launch: June 2015 - present		

2.2. Processing and analysis methodology

After obtaining Landsat-7 ETM+, Landsat-8 and Sentinel-2 data, different processes were applied to process then, create forest cover maps using NDVI-based classification approaches and for GIS-based change analysis. Figure 2 summarizes the flow chart of image processing and analysis in this research using ENVI 5.3.1, composing of 3 main steps: (1) processing of each image scene including radiometric calibration with QUAC model, geometric correction and georeferencing to the standard basemaps in VN2000 coordinate system with sub-pixel accuracy (with additional mosaicking and gap filling for Landsat-7 scenes) and NDVI calculation; (2) image classification using NDVI for each date into 4 categories of forest, other vegetation, non-vegetation and water bodies; and (3) thematic change detection analysis to create deforestation maps and reports during 2010–2015 and 2015-2016.

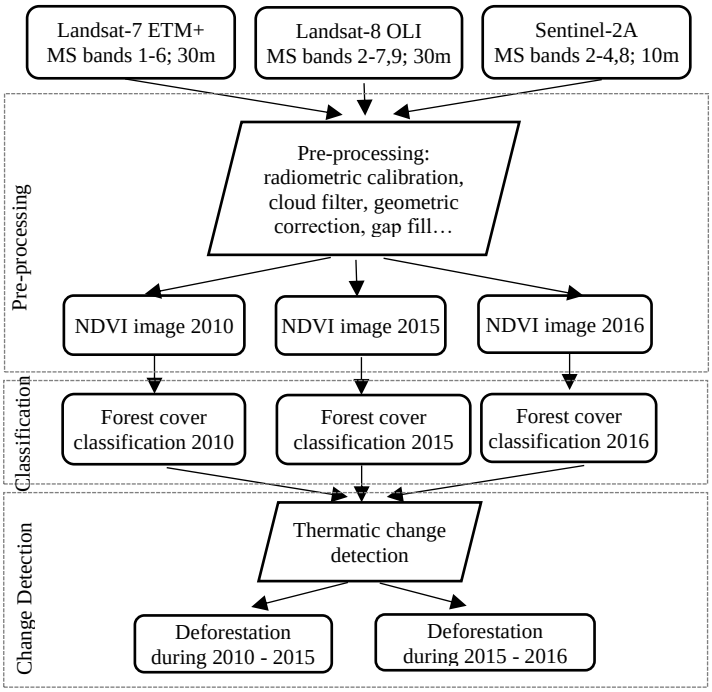

Fig. 2. Flowchart of the methodology used for deforestation detection in the study area.

The research was experimented with different image classification techniques such as minimum distance, maximum likelihood classification, segmentation / feature extraction, etc. Finally, the authors selected NDVI-based classification for its simplicity (with semi-automatic potential) and satisfied accurate delineation of forest from other non-forest land covers (e.g., other vegetation, water bodies and non-vegetation). The analysis also includes the re-sampling of classified 10m Sentinel-2A data to 30m to match Landsat data in order to create comparable forest cover maps of the study region. The classified data were combined with existing forest maps, ground-truthing data for post-classification processing and accuracy assessment. Rectified SPOT5 image-maps collected from the forest inventory (FORMIS) project were also used for results verification. The final results were integrated into the GIS forest database in order to build a WebGIS-based Forest Watch system for the Dak Nong province.

3. Results and discussions

3.1. Forest cover classification results

Figure 3 shows the classification results of the forest cover in Dak Nong province in 2010, 2015 and 2016 based on Landsat-7, Landsat-8 and Sentinels-2. Accuracy assessment based on 40 samples of reference data from ground-truthing and SPOT-maps shows good overall accuracy and kappa value of 91.77% & 0.8204; 92.08% & 0.8408; 94.85% & 0.8974; 97.41% & 0.9456 in the classification results of Landsat-7 2010, Landsat-8 2015, Landsat-8 2016 and Sentinel-2A 2016 images respectively. Comparing the classification results of Landsat-8 (25 April 2016) and Sentinel-2A MSI (4 March 2016) images shows a good comparability in 4 classified categories. A slightly better overall accuracy and better delineation of the semi-deciduous forest area from the Sentinel-2A image as compared to the Landsat-8 (Table 3) can be explained by its higher spatial resolution and acquisition date in relation to the dry ‘shedding leaves’ season. This shows clear potential of the Sentinel-2A data as a good complement of the Landsat series. The classified Sentinel-2A map was then, resampled to 30m for thematic change analysis.

a) b)

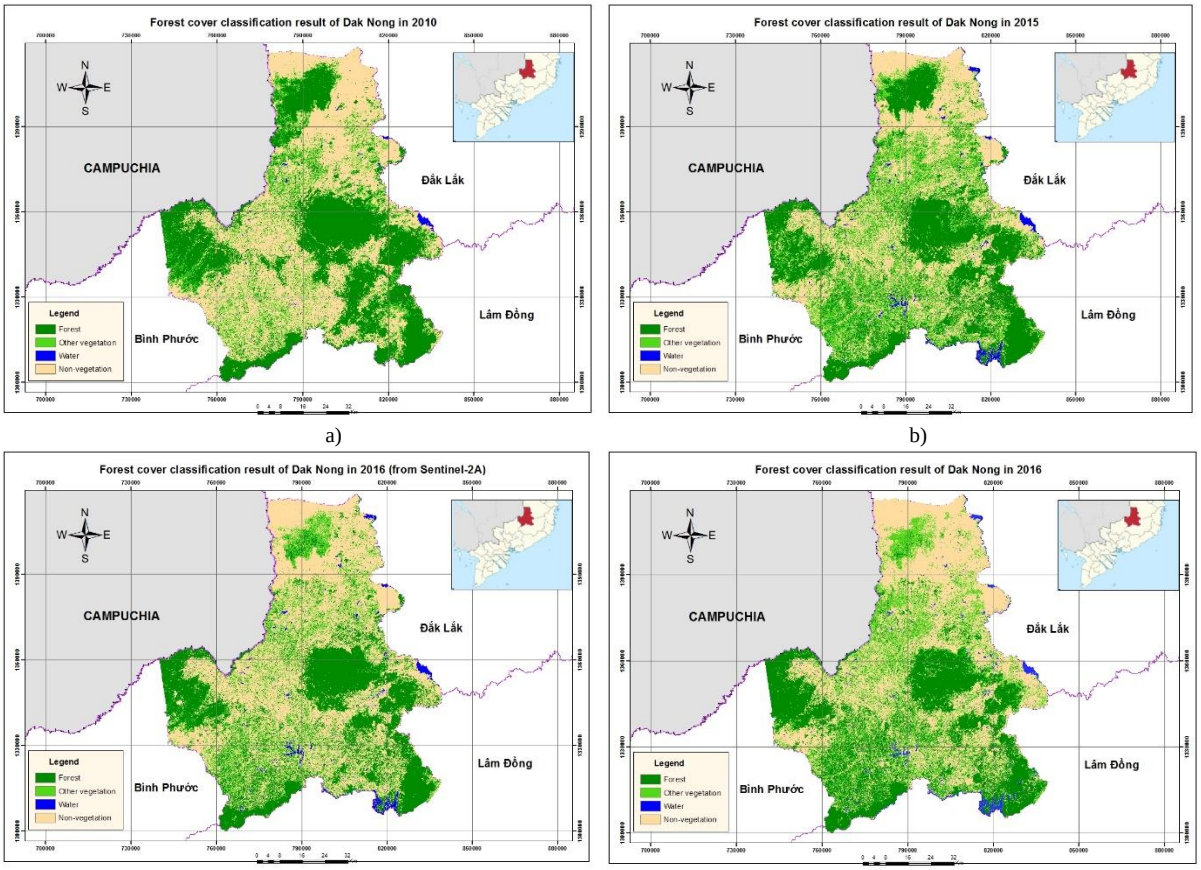

Fig. 3. Forest cover classification results from Landsat-7 2010 (a); Landsat-8 2015 (b); Sentinel-2A 2016 (c); and Landsat-8 2016 (d) images

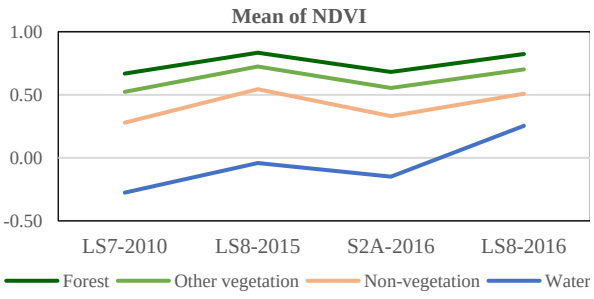

Fig. 4. Mean NDVI of 4 land cover classes in the study area for 4 processed satellite images

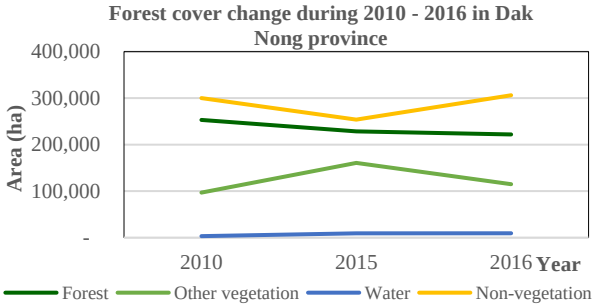

Fig. 5. Forest cover changes in Dak Nong area during 2010 - 2016 for each of 4 land cover classes based on satellite images

3.2. Deforestation in Dak Nong province during 2010-2016

Overall, the forest cover has a clear decreasing trend during the 2010 – 2016 period from 253,133 ha of total forest area in 2010, decreased to 228,576 ha in 2015 and further to 221,914 ha in March 2016 (including re-planted area, Table 3). As such, in less than 6 years (from 2010 to 2016), the forest cover in Dak Nong has a decrease of 31,219 ha, with the actual forest land loss much higher (and more severe in terms of forest quality) if considering province's great re-forestation efforts during the same period.

Table 3. Statistics of forest cover classification by Landsat-7, Landsat-8 and Sentinel-2A images during 2010 - 2016

Area (ha)	**Landsat-7** (16 March 2010)	**Landsat-8** (18 February, 2015)	**Sentinel-2A** (4 March 2016)	**Landsat-8** (25 April, 2016)
Forest	253,133	228,576	221,914	218,971
Other vegetation	96,775	160,643	114,899	124,937
Water	3,105	9,097	9,230	12,333
Non-Vegetation (bare soil, urban, industrial land…)	300,111	253,809	306,186	296,131

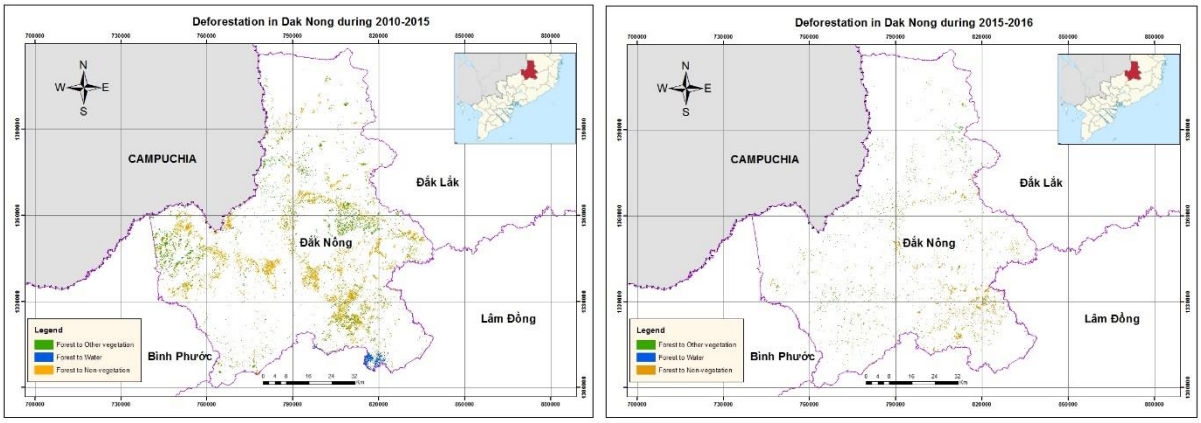

Fig. 6: Deforestation in Dak Nong province during a) 2010-2015 and b) 2015-2016

Figure 6 shows distribution of deforestation in various parts of the Dak Nong province. During 2010 – 2015, deforestation was concentrated in central part including Tuy Duc, Dak Glong, Dak Song, Krong No, Gia Nghia districts and partly in Dak Mil and Dak Rlap districts (Fig 6a). The deforestation is continuing into 2016 with new deforested areas appear in Dak Glong, Dak Song, Krong No, Tuy Duc districts (Fig. 6b). In details, Figure 7 shows several typical large deforested areas during 2010 – 2015 as visualized on Landsat images, representing major deforestation causes in Dak Nong province such as construction of large reservoir for Song Dong Nai 3 hydropower plant, primary evergreen forest converted into large-scale plantation of coffee, pepper, rubber or illegal timber cutting with some places were completely cleared / destroyed. In total, more than 200 large forest lots (with area of more than 0.5 ha) detected as deforested during 2010 – 2016 with land conversion summarized in Table 4, showing total forest loss of 46,528 ha during 2010 – 2015 and another 12,576 ha during 2015 - 2016.

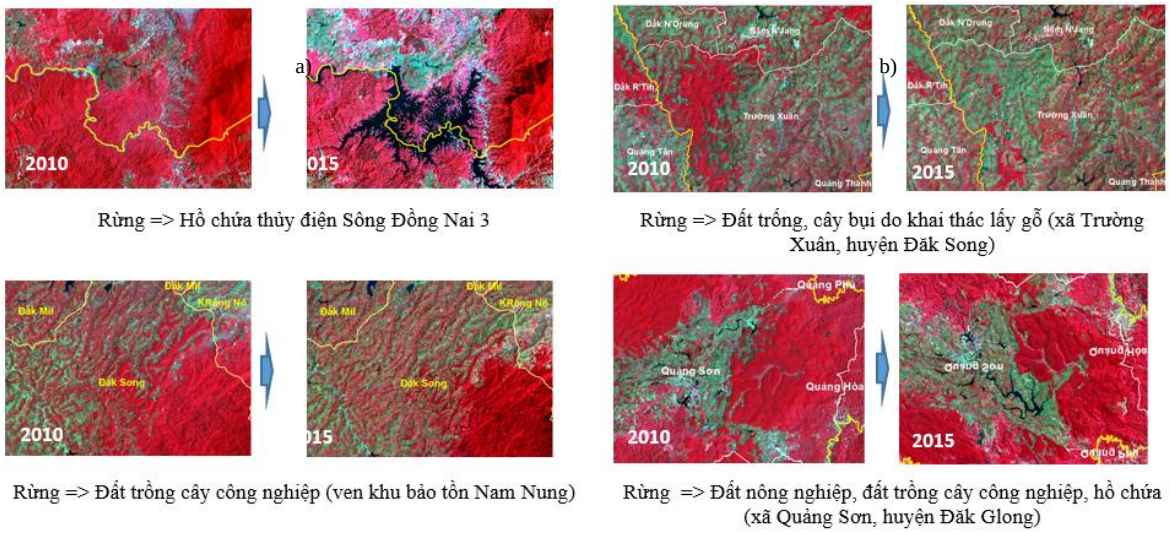

Figure 7: Examples of deforested areas in Dak Nong province during 2010 – 2015 as visualized on Landsat images

Table 4. Land use conversion statistics in Dak Nong province (from forest to other uses) during 2010-2016

Initial state	Final state	2010-2015	2015-2016
Forest	Other vegetation	16,716.14	4,147.87
Forest	Water	1,858.65	4.63
Forest	Non-vegetation	27,821.89	8,424.28
Total		46,528.63	12,576.78

3.3. Forest watch with WebGIS portal

The results of deforestation monitoring from satellite images with other GIS data were integrated into a comprehensive GIS forest database in support of effective forest management in the Dak Nong province. Figure 8 shows a prototype of a WebGIS-based Forest Watch portal for the Dak Nong province. With interactive

visualization, querying and statistical reporting functionalities, the system can provide comprehensive forest information, including up-to-date detailed deforestation maps (potentially integrated from 'semi-automatic' image processing sub-system) and related risk factors for forest protection authority to operationally monitor the forest resources in details and to prevent large-scale deforestation in the province.

Fig 8: A prototype of WebGIS-based forest watch portal for Dak Nong province

4. Conclusions and Future Work

Simple NDVI-based classification used in this research on the multi-sensor dataset of Landsat-7, Landsat-8 and Sentinel-2A images showed good accuracy in deforestation mapping in the Dak Nong province during 2010 - 2016. The results provided deforestation statistics in details for the 2010 – 2015 and 2015 – 2016 periods, shedding insights into the deforestation causes as well as delineating high-risk areas. Methodologically, the research demonstrated the practical use of multi-date, multi-sensor satellite data for regular forest mapping, which is more important for a 'cloudy' tropical country such as Vietnam. Specifically, it showed that Sentinel-2A with slightly better capabilities is a good complement to the Landsat, SPOT and VNREDSat-1 data in practical forest mapping. With increasingly free-available satellite data and tested image analysis routines, integration of derived deforestation maps into the prototype of WebGIS portal demonstrates a good prospective toward operational remote sensing in the forest sector. Toward that goal, future work will include: (1) improve NDVI-based classification and 'semi-automated' deforestation delineation; (2) integrate image processing routines into the WebGIS-based system to complete the analysis chain; and (3) further develop the WebGIS Forest Watch portal to include other deforestation risk factors such as forest fire 'hotspots' and field data with related user's functions as a platform to support effective forest management and timely forest protection at the provincial level 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.

ESA, 2015. Sentinel-2 User's Handbook.

Ouaidrari, H., Vermote, E. F., 1999. Operational atmospheric correction of Landsat TM data. Remote Sensing of Environment, 70(1): 4-15.

Topaloglu R.H., Sertel E., Musaoglu N., Assessment of classification accuracies of Sentinel-2 and Landsat-8 data for land cover / use mapping. The Int'l Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B8, 2016 XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic.

USGS, 2015. Landsat 8 (L8) Data User's Handbook.

In Vietnamese: Báo cáo Kết quả kiểm kê rừng tỉnh Đắk Nông 2014 (Viện Sinh thái Rừng và Môi trường, Trường Đại học Lâm nghiệp).