USING DUAL-POLARIZATION SENTINEL-1A FOR MAPPING VEGETATION TYPES IN DAKLAK, VIETNAM

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ABSTRACT: Sentinel-1A is a microwave satellite of European Space Agency (ESA) and was successfully launched in 2014. This satellite supports SAR (Synthetic Aperture Radar) data with C band, spatial resolution 10m, a cycle 12 days and free of charge. Sentinel-1A provide dual-polarization SAR image included in VV polarization and VH polarization data. Backscatter signal depends on the polarization, surface roughness of the objects and soil moisture. In this paper, the authors present the experience results using combinations of dual-polarization of Sentinel-1A images for mapping vegetation species. The combination of VV polarization and VH polarization used in this study included in $|VV+VH|$, $|VV-VH|$, VV/VH, RVI (Radar Vegetation Index) and PCA (Principal Component Analysis). The typical vegetations studied in this paper such as paddy rice, industrial trees, deciduous forest and evergreen forest. The classification SVM (Support Vector Machine) method was used in our study. The overall accuracy achieved 90.72% with Kappa index 0.8825. The study area is Ea Sup district, Dak Lak province in the Central Highlands region of Vietnam.

1. INTRODUCTION

Forests and plants play an important role in the region's socio-economic development and reduce global warming. Forests in Vietnam's Central Highlands has high biodiversity; rich in reserves, variety of species, especially the typical flora of deciduous forest. In addition, due to basalt soil, the Central Highlands region is suitable for industrial trees such as coffee, cocoa, pepper, mulberry and creals. However, the Central Highlands deforestation is increasing drammatically by human behavior. And industrial trees and agricultural crops are changed because of no long-term development plans.

Remote sensing images are the main data for monitoring and updating natural resources of Vietnam in general and of the Central Highlands in particular. The optical satellite images are usually used for remote sensing application based on the spectral characteristics of land cover objects. However, due to the location in the high mountains and the affection of tropical monsoon climate, there is hardly the cloudless optical satellite images in the Vietnam's Central Highlands in a year. SAR (Synthetic Aperture Radar) image which is an active microwave remote sensing data is used as an advantage material for monitoring natural resources and the earth environment because of uneffection by the atmosphere, day and night. In April 2014, Sentinel-1A satellite was successfully launched. Sentinel-1 satellite is the part of the European Space Agency's (ESA) development project for Earth observation satellite, which provides SAR data with band C, 400km swath width, spatial resolution from 5m, the cycle is 12 days and free of charge. Sentinel-1A provides dual-polarization data with VV and VH. Backscatter signal in SAR images which depends on surface roughness, electric conductivity and backscatter signal's polarization properties. In addition, the characteristics of canopy and stand structure of plants species, volume scattering and wavelength of microwave affect the backscatter signal of SAR images.

Many studies proposed the methods to classify land cover or vegetations by using dual-polarization or fully polarization SAR images. The interpretation method by SAR polarization images is based on the pseudo-color composite of SAR polarization images (Uhlmann and Kiranyaz, 2014). Dual-polarization SAR image is used for classification forests (Alena, *et al.*, 2018), (Dandy and Ryota, 2017), (Wijaya, *et al.*, 2010), agricultural crops (Dirk and Martin, 2003), (Leichtle, *et al.*, 2012), land-cover (Zhou, et al., 2018) and vegetation species (Li and Bijker, 2018). The classification method is mainly used a supervised classification method which the input data is the structure characteristics of surface objects (Uhlmann and Kiranyaz, 2014), (Hu, *et al.*, 2017), (Kasapoglu , 2011), (Zhou, *et al.*, 2018), SAR polarization combinations (Uhlmann and Kiranyaz, 2014), (Li and Bijker, 2018), (Zon, *et al.*, 2010) or correlation scattering matrix (Wijaya, et al., 2010), (Deng, *et al.*, 2008), (Kaan, *et al.*, 2004), (Leichtle, *et al.*, 2012).

Classification accuracy of the proposed methods achievedd 76% to 92% depending on microwave wavelength, spatial resolution or polarization properties of the experience data. The longer wavelength which are X band (TerraSAR-X) and L band (AIRSAR, ALOS PALSAR, PolSAR) penetrates and has volumn scattering more than C

band (Radarsat-2, Sentinel-1). According to that C band is often used for discriminating agricultural crops and the other plants. (Alena, *et al.*, 2018) proposed to use multi-temporal polarization Sentinel-1 for classifying forest/non-forest with achieved 86% accuracy and land cover in urban areas with 91.55% accuracy.

In this article, the authors proposed to map vegetation species by using the combination of dual-polarization Sentinel-1A images in Ea Sup district, Dak Lak province of Vietnam.

2. STUDY AREA AND MATERIALS

2.1. Study area

The study area is Ea Sup district which is a part of Dak Lak Province in the Central Highlands, Vietnam (Figure 1). It is far from Buon Ma Thuot city about 85km. Ea Sup is a remote and inaccessible area of Dak Lak province and has the low living standard. The elevation of Ea Sup is the lowest of Dak Lak province, about 160m-200m above sea level. The terrain is a flat plateau. In Ea Sup, there are two irrigation systems as Ea Sup Thuong and Ea Sup Ha which help to improve the irrigation conditions of this region. There is a large area of rice and fruit trees (mainly mangoes), industrial crops such as coffee and pepper ... The temperature of this area is high in a year. Ea Sup located in a region which is a relatively large rainfall with above 1,560 mm per year.

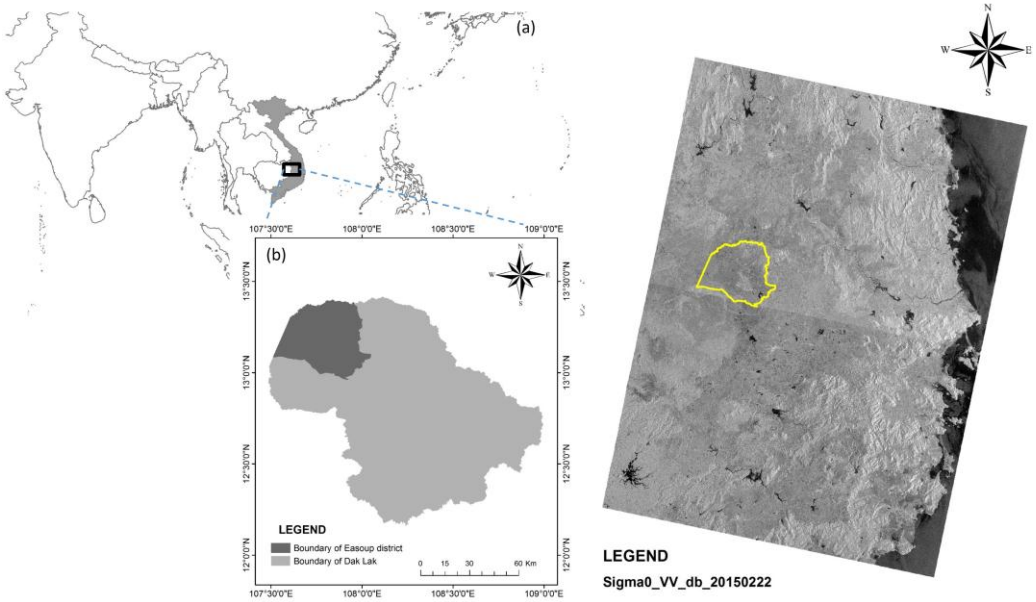

Figure 1. Study area Ea Sup district, Dak Lak, Viet Nam. (a) Location of Vietnam on the world map; (b) Location of Ea Sup district in Dak Lak Province, Vietnam; (c) Sentinel-1A image with VV polarization taken on 22/2/2015

The typical of plants in Ea Sup area including Dipterocarp forest (deciduous forest), evergreen forest, perennial and industrial trees and agricultural crops such as hybrid rice and inbred rice. Dipterocarp forest (deciduous forest) is a typical forest of the Central Highlands in Vietnam. However, due to economic development, the enterprises and human in Ea Sup destroyed a part of Dipterocarp forest area which is supposed to be low economic efficiency and replaced with industrial crops such as rubber, coffee, etc. Plant structure of Ea Sup is changed spontaneously by people. As a result it leads to effect to the development of this region. Therefore, the identification of the main vegetation types by using remote sensing data will help to monitor and to be sustainable development of Ea Sup region.

2.2. Materials and pre-processing

The experience materials were Sentinel-1A satellite images with Level-1 GRD processing level, spatial resolution 10m, dual-polarization VV and VH and acquisition on February 22, 2015 (Figure 1c).

Table 1. The characteristics of the experience material

The characteristics	Sentinel-1A data
Acquisition time	22/02/2015
Acquistion mode	IW (Interferometric Wide swath)
Level	Level 1 - GRD
Polarization	VV and VH
Spatial resolution	10m
Bit depth	16 bit

The characteristics of the experience data are shown in Table 1. The pre-processing of Sentinel-1A data included in five steps: (*i*) Thermal noise removal; (*ii*) Radiometric calibration to sigma nought value (σ^0); (*iii*) Range-Doppler terrain correction using the Shuttle Topography Mission Radar (SRTM); (*iv*) Conversion from linear to dB; (*v*) Filter noise using Lee algorithm (3x3 size). The pre-processing steps were performed using the SNAP toolbox software which is provided by the European Aerospace Agency.

In addition, the field data which were applied for visual interpretation and validation the classification results are Landsat 8 OLI satellite images taken on March 6, 2015 and Land use map in 2015 of Dak Lak province with 1:100.000 scale.

3. METHODOLOGY

3.1. The characteristics of backscatter signal of dual-polarization images

The properties of backscatter signals on SAR image are scatter signals which are come back from the objects. The roughness of surface objects effects backscatter signals and the brightness on the SAR image. In addition, the scattering signals of SAR image depend on the polarization properties of transmitted signal and received signal at the sensor. Currently, microwave satellite systems use usually linear polarization, in which RADAR signals are transmitted and received at horizontal (H) or vertical polarization (V). For vegetation objects, the difference of signal wavelength, canopy and the vertical structure of trees will changes the received backscatter signals on SAR images (Figure 2).

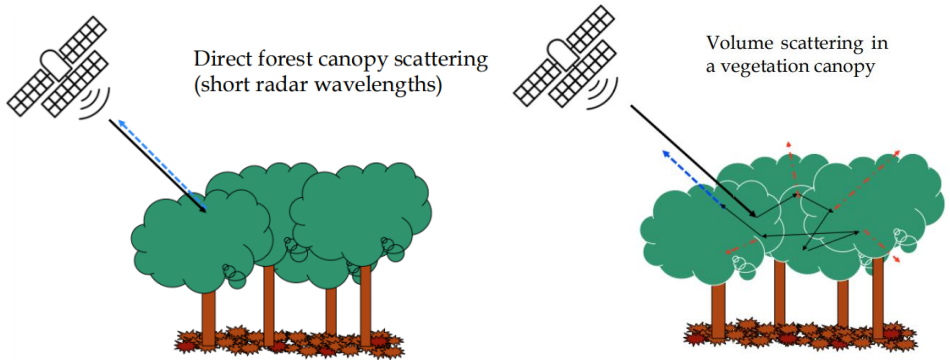

Figure 2. Backscatter signals at forest positions (Layman, 2018)

Therefore, vegetation types have difference backscatter value in polarization SAR images because of the characteristics canopy (Figure 3a, Figure 3b). In Figure 3c, the location in B is barren objects and the location in A, C, D, and E are plant objects. Based on the RGB composite of Landsat 8OLI image (Figure 3c) and Land use mapping of Dak Lak province in 2015, the visual interpretation of the position A is paddy rice, the position C is deciduous forest (in dry season); the position D is perennial trees or industrial trees and the position E is evergreen forest (in dry season). Comparison with the corresponding positions on the VV polarization and VH polarization image, there are the difference brightness at the same positions. The position at deciduous forest, industrial trees, barren land on VH polarization image have higher value than the corresponding positions on VV polarizing image.

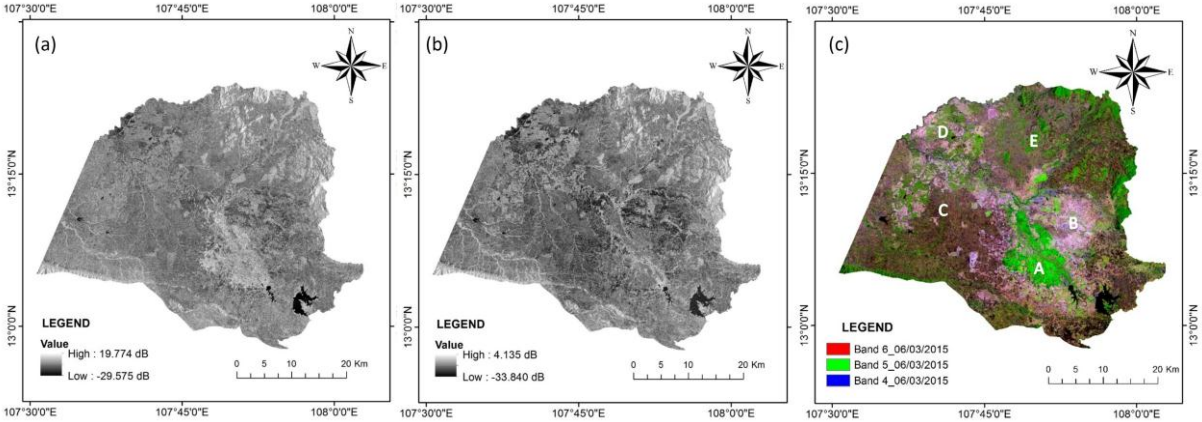

Figure 3. Backscatter values on VV polarization and VH polarization. (a) VV polarization image; (b) VH polarization image; (c) The composite RGB of Landsat 8OLI

3.2. The combination of dual-polarization Sentinel-1A

Many studies used to the difference combination of polarization SAR images such as $|VV+VH|$, $|VV-VH|$, VV/VH, RVI index và PCA for classification land cover. Figure 4 shows the difference intensity values in these

polarization combinations images. Comparison between the polarization combination images and the composite of Landsat 8OLI, we can see the constrast of plants regions in the centre of Ea Sup district.

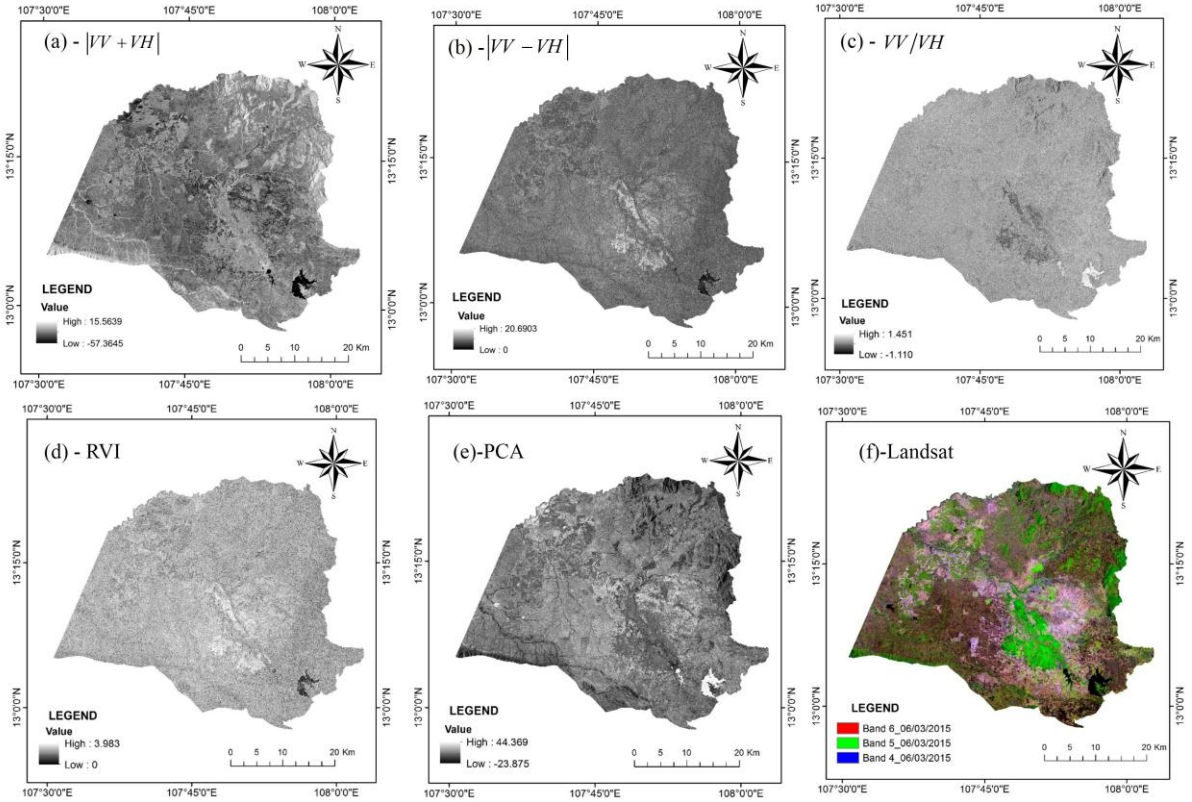

Figure 4. (a) $|VV + VH|$ image; (b) $|VV - VH|$ image; (c) VV/VH image ; (d) RVI index image; (e) PCA image; (f) The RGB composite of Landsat 8 acquisition on 06/03/2015.

Figure 5 shows the RGB composite of dual-polarization original and the polarization combination in the central of Ea Sup district. Based on visual interpretation on the RGB composite of Landsat 8OLI image (Figure 5f), there are some vegetation regions with green color. However, it is clear that there are the kind of vegetation types on the polarization combinations including paddy rice and perennial fruits along the Serepok River, deciduous forest and evergreen forest in the dry season and industrial trees. According to the analysis of backscatter value in dual-polarization Sentinel-1A and in polarization combination images, the authors proposed five polarization combinations of SAR image in Table 2 for classification vegetation types in the study area.

Table 2. The polarization combinations of SAR images

No	Dual-polarization combination	Bands of the experience data
1	$\|VV + VH\|$	VV, VH, $\|VV + VH\|$
2	$\|VV - VH\|$	VV, VH, $\|VV - VH\|$
3	VV/VH	VV, VH, VV/VH
4	RVI (Radar Vegetation Index)	VV, VH, RVI
5	PCA (Principle Component Analysis)	VV, VH, PCA (the first component)

The vegetation index of polarization SAR image (denoted by RVI - Radar Vegetation Index) was proposed by (Kim and van Zyl 2004, 2009). (Kim and van Zyl 2004, 2009) proposed RVI index of full polarization image with VV, HH, VH, and HV polarization. However, (Charbonneau, *et al.*, 2005) assumed $\sigma_{HH} \approx \sigma_{VV}$ and proposed Equation (1). As a result, RVI index of dual-polarization SAR image is determined as follows:

$$RVI = \frac{4\sigma_{VH}}{\sigma_{VV} + \sigma_{VH}} \quad (1)$$

Where: σ_{VV} - Sigma nought value of VV polarization; σ_{VH} - Sigma nought value of VH polarization; Units of polarization coefficients in Equation (1) are defined as energy units (power units).

. Based on Equation (1), the conversion equation from dB units to power units is as follow:

$$RVI = \frac{10^{4|\sigma_{VH}dB|/10}}{10^{|\sigma_{VV}dB|/10} + 10^{|\sigma_{VH}dB|/10}} \quad (2)$$

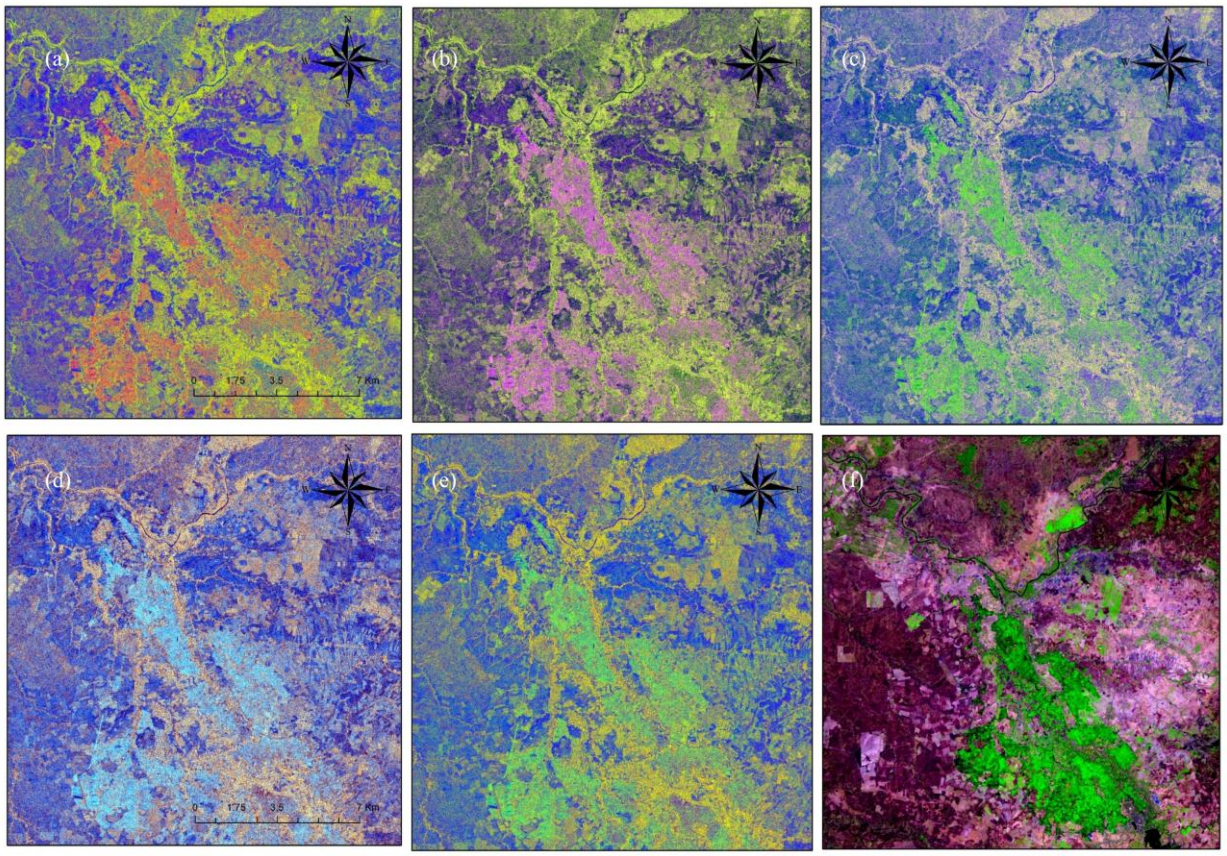

Figure 5. Comparison of SAR polarization combinations at the central area of Ea Sup district. (a) $|VV+VH|$ combination image; (b) $|VV-VH|$ combination image; (c) VV/VH combination image; (d) RVI index combination image; (e) PCA-P1 combination image; (f) The RGB composite of Landsat 8OLI acquisition on 06/03/2015

According to Land use map of Dak Lak province with 1: 100.000 scale, the main vegetation types in the study area included in paddy rice (hybrid rice and inbred rice), perennial trees (industrial trees, perennial fruits), deciduous forest, evergreen forest. In addition, these vegetation types had the difference kinds of color on the polarization composite images (Figure 5(a), (b), (c), (d)). The classification samples on the polarization combinations SAR images were chosen based on the visual interpretation on the RGB composite of Landsat 8OLI and Land use map of Dak Lak province.

4. RESULTS AND DISCUSSION

4.1. Results and validation

The SVM (Support Vector Machine) classification method was used to classify vegetation types by using SAR polarization combinations. The classification layers were paddy rice, industrial trees, deciduous forest, evergreen forest and others (water, barren, built-up land). Figure 5 shows the vegetation types map in Ea Sup district was classified by using RVI index combination which was the fourth case in Table 2. The assessment accuracy of classification results is shown in Table 3 and Figure 6. The overall accuracy and Kappa index of classification results of the polarization combination SAR images are shown in Table 2. The highest overall accuracy achieved 90.72% and Kappa index 0.88 with RVI index combination polarization. Figure 6 shows the comparison classification accuracy of vegetation types which were classified by polarization combinations of SAR images.

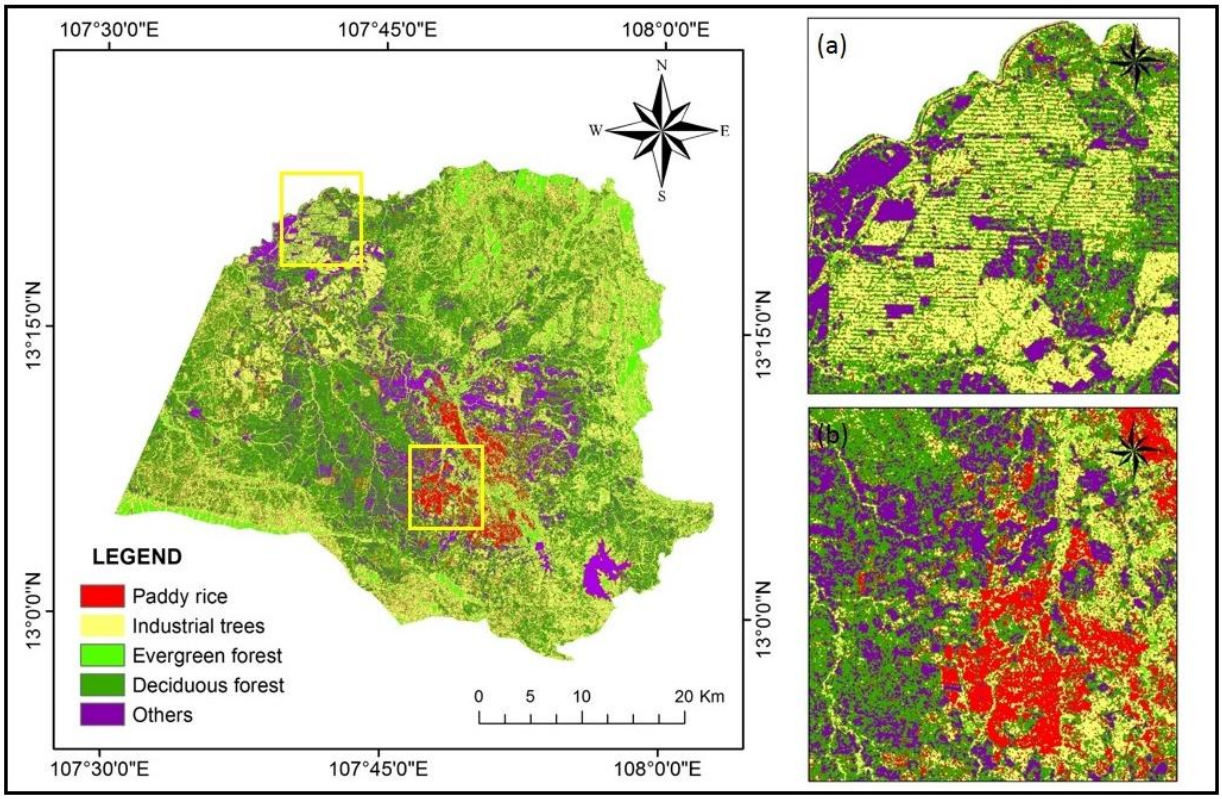

Figure 5. Mapping of vegetation types in Ea Sup district, Dak Lak province, Vietnam

Table 3. Classification accuracy assessment accuracy of polarization combinations of SAR image

	$\lvert VV+VH \rvert$	$\lvert VV-VH \rvert$	VV/VH	RVI	PCA
Overall accuracy	87.1872	90.4875	90.5306	90.7248	87.2088
Kappa index	0.8376	0.8795	0.8800	0.8825	0.8378

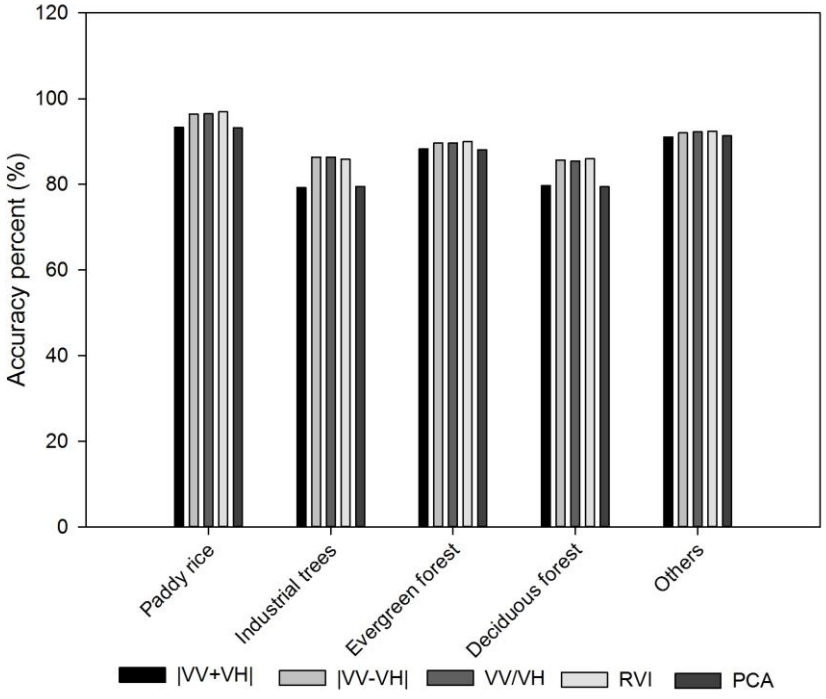

Figure 6. Comparison classifcation accuracy of objects on polarization combinations

4.2. Discussion

According to the results in Figure 5, Figure 6 and Table 3, the mapping of vegetation types by using difference of SAR polarization combinations high accuracy. The polarization combination as (VV, VH, $|VV+VH|$) and (VV, VH, PCA) had the lowest accuracy with an overall accuracy of 87.2% and $K \approx 0.838$. The polarization combination as (VV,VH, $|VV-VH|$) và (VV,VH, VV/VH) had overall accuracy respectively 90.48% and 90.53%. The (VV, VH, RVI) combination had the highest accuracy with 90.72% overall accuracy and $K \approx 0.8825$. RVI which is a vegetation index is determined by backscatter signal of polarization SAR image. So that the vegetation types in RVI index image had contrast to the others (Figure 4(d) and Figure 5(d)). Therefore, the classification accuracy of vegetation types by using RVI polarization combination is higher than another combination. In figure 6, it shows the comparison of classification accuracy of vegetation types which were classified by using polarization combination SAR image. The classification accuracy of vegetation types also proved RVI polarization combination with the highest accuracy. Besides, the classification accuracy of paddy rice was higher than the other vegetation objects (Figure 6).

To assess the accuracy of the classification results, the authors compared the classification result to Land use map in 2015 of Dak Lak province and Landsat 8 color composite image. As a result, paddy rice and industrial trees were classified with high accuracy (Figure 7). However, the misclassification are evergreen forests which are in high moutainous areas (due to the effection of geometric deformation on SAR image) and industrial trees were mixed with evergreen forest because of the similar canopy structure. In addition, speckle noise in SAR image caused some noise to the classification results.

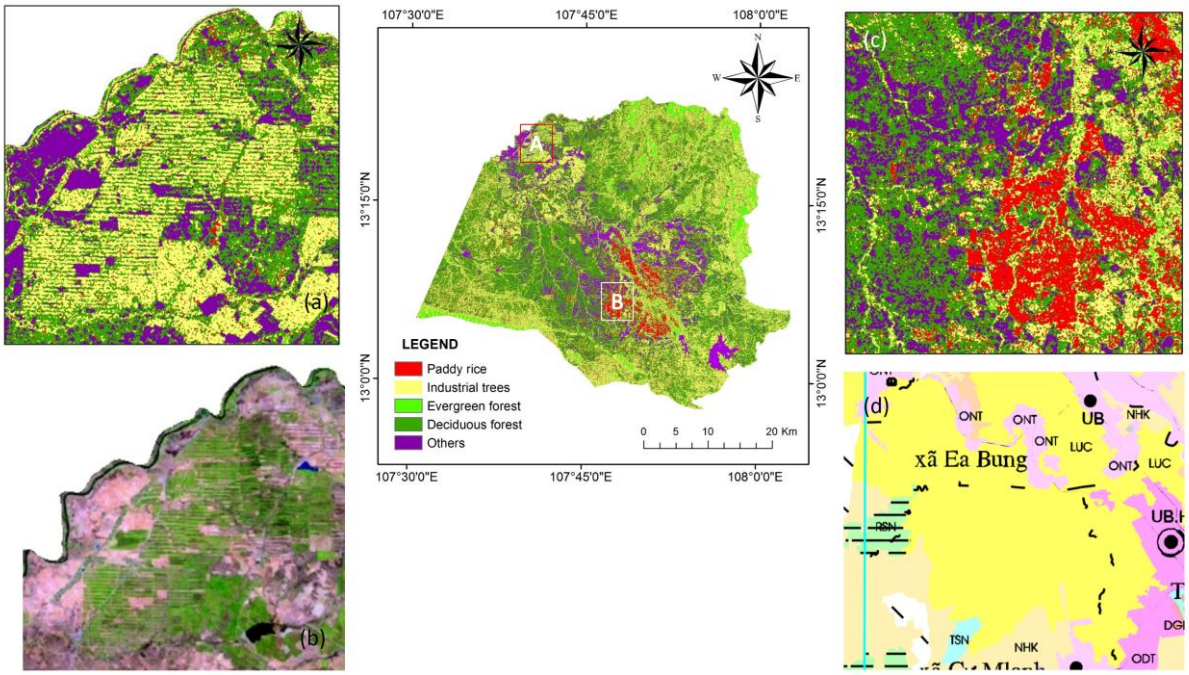

Figure 7. Validation result classification at location A (industrial trees) and location B (paddy rice). (a) The classification result at location A; (b) Composite of Landsat 8 at location A; (c) The classification result at location B; (d) Land use maps at location B

5. CONCLUSION

In conclusion, the vegetation types can be classified by dual-polarization Sentinel-1A with high accuracy. The vegetation types are the difference kinds of color on SAR polarization combination. It proved that the canopy structure of vegetation types affects backscatter signals on dual-polarization Sentinel-1A. The experience result proved that the classification accuracy of (VV, VH, RVI) polarization combination was the highest accuracy with 90.72% overall accuracy and kappa index 0.8825. In addition, paddy rice which was classified by dual-polarization Sentinel-1A with C-band was higher classification accuracy than the other vegetation types. In the future, we study applying multi-temporal dual-polarization Sentinel-1A for monitoring plants and natural resources of the Central Highlands, Vietnam.

REFERENCES

Alena, D., Wolfgang, W., Milutin, M., Markus, H., 2018. Annual seasonality in Sentinel-1 signal for forest mapping and forest type classification. *International journal of remote sensing*, https://doi.org/10.1080/01431161.2018.1479788

Charbonneau, F., Trudel, M., Fernandes, R., 2005. Use of Dual Polarization and MultiIncidence SAR for soil permeability mapping. *In: Advanced Synthetic Aperture Radar (ASAR) 2005*, St-Hubert, Canada.

Dandy, A. N., Ryota, N., 2017. Polarimetric synthetic aperture radar application for tropical peatlands classification: a case study in Siak River Transect, Riau Province, Indonesia. *Journal of Applied Remote Sensing*, Vol 11(1), pp 16-40, doi: 10.1117/1.JRS.11.016040

Deng, Q., Chen, Y., Zhang, W., Yang, J., 2008. Colorization for Polarimetric SAR Image based on Scattering Mechanisms. *IEEE computer society (Congress on Image and Signal Processing 2008)*, DOI 10.1109/CISP.2008.366

Dirk, H. H., Martin, A. M. V., 2003. A New Polarimetric Classification Approach Evaluated for Agricultural Crops. *IEEE transactions on geoscience and remote sensing*, Vol. 41, No. 12, pp. 2881-2889.

Hu, J., Ghamisi, P., Zhu, X. X., 2018. Feature Extraction and Selection of Sentinel-1 Dual-Pol Data for Global-Scale Local Climate Zone Classification. *International Journal of Geo-Information*, Vol 7 (379), doi:10.3390/ijgi7090379

Kasapoglu, N. G., 2011. Synthetic Aperture Radar Feature Selection for Dual Polarized ScanSAR Data. *Proc of 5th International Conference on Recent Advances in Space Technologies - RAST2011*, pp. 370-374, DOI: 10.1109/RAST.2011.5966858

Kaan, E., Bernd, S., Ian, C., 2004. Incorporating Texture Information into Polarimetric Radar Classification Using Neural Networks. *Proc IGARSS 2004 (2004 IEEE International Geoscience and Remote Sensing Symposium)*, pp. 560-563, DOI: 10.1109/IGARSS.2004.1369088.

Kim, Y., van Zyl, J, 2004. Vegetation effects on soil moisture estimation. Geoscience and Remote Sensing Symposium. *In Proceedings of the IEEE International 2004, IGARSS '04*, Anchorage, AK, USA, 20–24 September 2004; Volume 2, pp. 800–802.

Kim, Y.J., VanZyl, J., 2009. A time-series approach to estimate soil moisture using polarimetric radar data. IEEE Trans. *Geosci. Remote Sens*. Vol. 47, 2519–2527.

Leichtle, T., Schmitt, A., Roth, A., Schardt, M., 2012. On the capability of different SAR polarization combinations for agricultural monitoring. *Proc 2012 IEEE International Geoscience and Remote Sensing Symposium*, pp. 3752-3755, DOI: 10.1109/IGARSS.2012.6350501.

Layman, 2018. A Layman's interpretation Guide to L-band and C-band Synthetic Aperture Radar data. *Version 2.0, 15 Nov, 2018*.

Li, M., Bijker, W., 2018. Potential of multi-temporal sentinel-1a dual polarization SAR images for vegetable classification in Indonesia. *Proc of IGARSS 2018*, pp. 3820-3823, DOI: 10.1109/IGARSS.2018.8517325.

Uhlmann, S., Kiranyaz, S., 2014. Classification of dual- and single polarized SAR images by incorporating visual features. *ISPRS Journal of Photogrammetry and Remote Sensing*, 90(2014), pp 10-22. http://dx.doi.org/10.1016/j.isprsjprs.2014.01.005

Wijaya, A., Marpu, P. R., Gloaguen, R., 2010. Discrimination of peatlands in tropical swamp forests using dual-polarimetric SAR and Landsat ETM data. *International Journal of Image and Data fusion*, Vol 1, No. 3, pp. 257-270.

Zhou, T., Li, Z., Pan, J., 2018. Multi-Feature Classification of Multi-Sensor Satellite Imagery Based on Dual-Polarimetric Sentinel-1A, Landsat-8 OLI, and Hyperion Images for Urban Land-Cover Classification. *Sensors*, Vol 18 (373), doi:10.3390/s18020373

Zou, T., Yang, W., Dai, D., Sun, H., 2010. Polarimetric SAR Image Classification Using Multifeatures Combination and Extremely Randomized Clustering Forests. *EURASIP Journal on Advances in Signal Processing*, Vol. 2010, ID 465612, doi:10.1155/2010/465612
http://www.tapchicongsan.org.vn/Home/PrintStory.aspx?distribution=43876&print=true