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Management current land use of perennial industrial crops by NDVI index: A case study in Chu Se District, Gia Lai Province, Vietnam

Quản lý hiện trạng đất trồng cây công nghiệp lâu năm bằng chỉ số NDVI: trường hợp nghiên cứu tại huyện Chư Sê, tỉnh Gia Lai, Việt Nam

Research article

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Remote sensing and Geographic Information System (GIS) - an effective tool for managing natural resources, is quite common application in establishing thematic maps. However, the application of this modern technology in natural resource management has not yet been popular in Vietnam, particularly mapping the land use/cover. Currently, land use/cover map is constructed as traditional methods and gets limitations of management counting due to time-consuming for mapping and synthesis the status of land use/cover. Hence, information on the map is often outdated and inaccurate. The main objective of this study is to upgrade the accuracies in mapping current perennial crops in Chu Se District, Gia Lai Province in Vietnam by interpreted NDVI index (Normalized Difference Vegetation Index) from Landsat 8-OLI (Operational Land Imager). The results of study is satisfied the urgent of practical requirement and scientific research. There are 3 types of perennial industrial plants in the study area including rubber, coffee, and pepper, in which most coffee is grown, with an area of over 10,000 hectares. The results also show that integration of remote sensing and GIS technology enables to map current management and distribution of perennial industrial plants timely and accurately. This application is fully consistent with the trend of the world, and in accordance with regulations of established land use/cover map, and the process could be applied at other districts /towns or in higher administrative units.

Viễn thám và hệ thông tin địa lý (GIS) là công cụ hữu hiệu để quản lý tài nguyên thiên nhiên, được ứng dụng khá phổ biến để thành lập các loại bản đồ. Tuy nhiên, việc áp dụng công nghệ hiện đại này trong lĩnh vực quản lý tài nguyên thiên nhiên ở Việt Nam chưa phổ biến, nhất là công tác xây dựng bản đồ hiện trạng sử dụng/độ phủ đất. Việc xây dựng bản đồ hiện trạng hiện nay vẫn theo phương pháp truyền thống, thường gặp nhiều hạn chế do thời gian tổng hợp và xây dựng bản đồ hiện trạng kéo dài, dẫn đến thông tin trên bản đồ bị lạc hậu và không chính xác. Mục tiêu chính của nghiên cứu này là nâng cao độ chính xác kết quả giải đoán ảnh viễn thám Landsat 8 bằng chỉ số NDVI (chỉ số khác biệt thực vật) để thành lập bản đồ hiện trạng sử dụng đất cây công nghiệp lâu năm ở huyện Chư Sê, tỉnh Gia Lai, Việt Nam. Từ đó quản lý hiện trạng sử dụng loại đất này phù hợp yêu cầu cấp bách thực tiễn sản xuất và nghiên cứu khoa học. Kết quả của nghiên cứu cho thấy có 3 loại hình cây công nghiệp trên địa bàn nghiên cứu gồm cây cao su, cà phê và hồ tiêu, trong đó cây cà phê được trồng nhiều nhất, với diện tích hơn 10.000 ha. Nghiên cứu cũng cho thấy, tích hợp công nghệ viễn thám và GIS cho phép quản lý hiện trạng và phân bố cây công nghiệp trong không gian một cách hiệu quả và nhanh chóng. Ứng dụng này hoàn toàn phù hợp với xu hướng của thế giới, đồng thời theo đúng quy định thành lập bản đồ hiện trạng sử dụng đất, và quy trình này có thể thực hiện được ở cấp huyện/thị xã hoặc đơn vị hành chính cấp cao hơn.

Keywords: GIS, land use/cover map, perennial industrial crops, remote sensing

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1. Introduction

Perennial industrial crop has played an important role in exploiting the strength of hills, mountainous areas, and midlands in Vietnam, breaking monoculture in agriculture, restricting deforestation as well as protecting natural resource (Department of Rural Development and Natural Resources, 2006). Under the impact of economic market, the structures and areas of various perennial industrial crops have been changed rapidly. Besides, the development of industrial crops is also significantly affected by the weather or disease, especially rubber (Nguyen, Sinh Cuc, 2009). Such factors leading the current state of perennial industrial plant fluctuate continuously. Therefore, constructing timely and accurately a map of current industrial plants under the strong impact of natural disasters, people and economic-social development is necessary for considering.

Currently, various methods are utilized to build land use/cover map. In which, remote sensing technology is known as a common method and exhibit its superiority in investigating and managing natural resources. Even though there are some studies related remote sensing for managing natural resource, the applications of this technology in building land use/cover map are limited still available in Vietnam. For example, the case study at Khai Quang Ward, Vinh Yen City, Vinh Phuc Province (Kieu, Thi Kim Dung, 2009), land use change was mapped by using SPOT satellite imagery with high-resolution. Although the output maps had high precision, it is difficult to apply in to practice due to their high cost. In addition, the author confused in differentiating land use/cover types leading the uncertainty in result of study. Another study in mapping land use/cover state using medium spatial resolution image - Landsat 7 (Nguyen, Thi Dieu, 2012), free satellite image, showed the different between spectral samples, such as: spectral pattern between protection forest and production forest, or spectral patterns between rice and secondary crops, which help output maps matching the reality of land use/cover at study site. Besides, the cost for mapping land use/cover was also lower than using SPOT image. However, this study is just stopped at doing land use/cover map based on the simple interpretation process of spectral patterns. Therefore, the accuracies of results were not so high.

From practical problems and limitations of the previous studies, the aim of this subject is to upgrade the accuracy of process in mapping land use/cover from medium spatial resolution image (Landsat 8) by combining NDVI (Normalized Difference Vegetation Index) in Chu Se District, Gia Lai Province, where has large area of perennial industrial crops in Vietnam.

2. Materials and methodologies

2.1. Materials

The primary data used in this study was Landsat 8 satellite image with 30m spatial resolution taken free from Earth Explorer (http://earthexplorer.usgs.gov/), a website of United States Geological Survey (USGS). Among available satellite imagery, LC81240512014030LGN00 scene acquired on 30th May 2014, 0.25% cloud cover, and good quality was chosen. This scene is perfect and fit with aim of research study in using treatment processes and analysing land use/cover of perennial industrial crop in Chu Se District, Gia Lai Province.

2.2. Research methodologies

2.2.1. Collecting secondary data

Non-spatial data, including natural conditions, economic-social statistics, and land inventory statistic in 2013, were collected in reports Statistics Yearbooks, and documents from agriculture office at study site. Whereas, spatial data, including current maps of land use in 2010 (scale 1:25.000), topographical map 2000 (1:50.000) and administrative map were collected from Natural resource and Environment office in Chu Se district, Gia Lai province. These maps were used to correct the geometry of satellite images.

2.2.2. Fieldwork surveying

Surveying and investigation were conducted under systematic strategy to collect primary samples representing perennial industrial crops in Chu Se District, Gia Lai Province. Total of 240 Ground Control Points (GCPs) in corresponding with 43 samples of land were selected, depending on the distribution of each type of crops in study area. Besides, officers at Natural Resources and Environment office were interviewed to get more information about land use/cover in 2013 at Chu Se District, Gia Lai Province, especially the current state of perennial industrial crops.

2.2.3. Interpreting remote satellite images

In this study, the digital topographical map 1/50.000 of 2000 was used as reference data. The Landsat 8 image was geo-referenced by an average of 25 well-distributed GCPs to Universal Transverse Mercator (UTM) coordinate system, Datum WGS 84, Zone 48 North by image-to-map rectification. The achieved Root Mean Square Error value (RMSE) of transformation was below 0.5 pixels. Landsat 8 image was then classified as Maximum likelihood algorithm, by different training areas, which were delineated and verified by reference maps and the visual interpretation. The accuracies of different types of land use/cover were assessed. Consequently, interpreted land use map on perennial industrial crops at Chu Se District, Gia Lai Province was edited in accordance with regulations of the Ministry of Natural Resources and Environment of Vietnam.

2.2.4. Calculating NDVI

The Normalised Difference Vegetation Index (NDVI) is a standard algorithm, which is designed to estimate the amount of aboveground green vegetation cover from measurements of red and near-infrared reflectance. NDVI is calculated as following formula:

$$NDVI = (NIR - Red)/ (NIR + Red) \qquad (1)$$

In which, Red and NIR is stand for the spectral reflectance measurements acquired in the red and near-infrared regions, respectively. NDVI itself thus varies between -1.0 and +1.0. Vegetated areas will generally yield high values because of their relatively high near-infrared reflectance and low visible reflectance (Carlson T.N. and Ripley D.A., 1997).

2.2.5. Accuracy assessment

As pointed out by (Johannsen et al., 2003), remote sensing data have become more important for environmental analysis at different scales. Hence, it is needed to assess the accuracy of thematic map and give evidence for implementing the next steps. In this study, the Kappa coefficient (K) has been believed to be a powerful tool, which is used as a measure of agreement between model predictions and reality (Congalton, 1991) or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen, 1996). It ranges from 0 to 1 and indicates the proportional reduction of error, done by a factor completely random classification (Treitz et al., 1992). K index is calculated by the following formula:

$$K = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})} \qquad (2)$$

Where, N is total number of counts in the confusion matrix; r is the number of rows in the matrix; x_{ii} is the number in row i and column i; x_{i+} is the total for column i; x_{+i} is the total for row i (Jensen, 1996).

3. Results and discussions

3.1. Image processing

3.1.1. Selecting composites of standard false color

As mentioned above, previous studies just interpreted remote satellite images from one composite of standard false colour. However, each channel is capable of describing the reality differently. Hence, selecting appropriate combination of spectral channels that consists with the purposes of the study plays an important role. In this study, to improve the precision of building land use map, the authors decided to choose different combinations of false colour channels of Landsat 8, which are adequate for clearly differentiating areas for perennial industrial crops (including pepper, rubber, coffee) with areas for other crops, such as paddy crop, annual crops (cassava, maize, peanuts...). Different combination bands of Landsat 8 image were tested and displayed to create different composite effect and increased information on land use/cover, combined with field survey, the following colour combinations were selected (Table 1).

Table 1. Composite of standard false color for study

Name	Band RGB
Natural Colour	432
Colour Infrared Vegetation	543
Vegetation Analysis	654

3.1.2. Identifying NDVI for study site

As mentioned in 2.2.4 section, NDVI is normally used to assess the development of green plants, which could be track and monitor the changes of vegetation over time. Because this study focuses only on creating land use map of perennial industrial crops, so it is significant to identify the distribution of concerned vegetation. It is shown that NDVI is calculated from band 4 and band 5, corresponding to red and near-infrared spectral, respectively. Thus, we chose images of false color 543 and 654 for conducting vegetation index NDVI. In general, there is no different between NDVI maps conducted from image 543 and image 654 (Figure 1). Therefore, we could use one of these maps for further analysis.

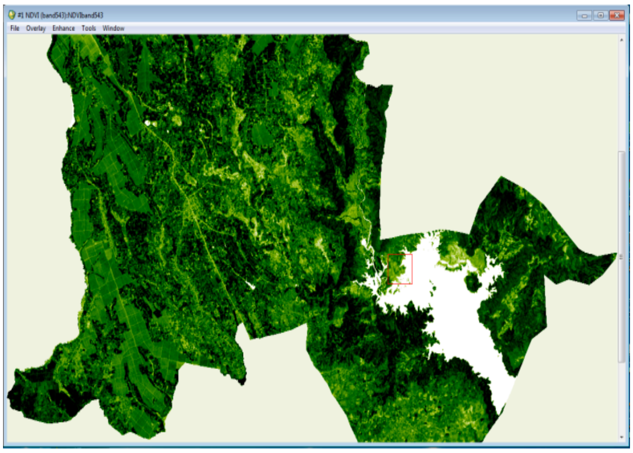

Figure 1. NDVI map from composit of false colour 543

The analytical results showed that the areas that values of NDVI index were under 0.5, had no vegetation or were sparse and poorly developed. Conversely, the value of NDVI index ranged from 0.5 to 0.9 showed the presence of well-developed plants, including perennial industrial crops, fruit trees, or forest. In this study, to determine the perennial industrial crops, the authors did some field tests and realized that special crops had their own characteristics, with values of NDVI fluctuated from 0.67 to 0.84. As can be seen in Figure 1, land covered in pale blue square areas and located mainly in the west of Chu Se District were the planted rubbers. The blue areas around the rubber plantations were growing coffee and pepper areas. This information was useful for next classification step.

3.2. Image classification

In this study, we decided to classify Landsat 8 image by both methods supervised classification and unsupervised classification. Accordingly, the results of unsupervised classification were considered as the base to determine trained samples of supervised classification technique.

3.2.1. Unsupervised classification

ISODATA (Iterative Self- Organizing Data Analysis) technique in unsupervised classification was chosen to calculate class mean evenly distributed in the data space then iteratively clusters the remaining pixels using minimum distance techniques. All pixels are classified to the nearest class unless a standard deviation or distance threshold is specified, in which case some pixels may be unclassified if they do not meet the selected criteria. This process continues until the number of pixels in each class changes by less than the selected pixel change threshold or the maximum number of iterations is reached. Within the scope of the subject, ISODATA technique was done completely automatically for NDVI images, without input parameters. The results showed that there were 5 classified objects, displayed in different colours (Figure 2 and Table 3).

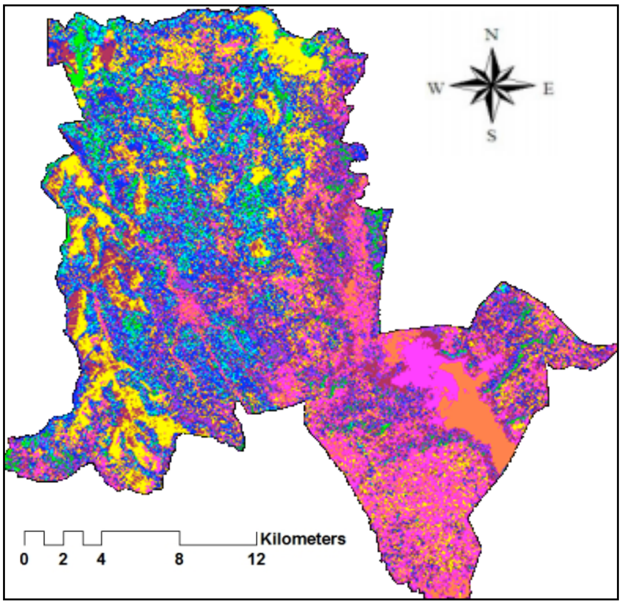

Figure 2. Result of unsupervised classification ISODATA

Table 3. Classified objects from NDVI image

Object	Colour	Description
1	Yellow	Land for premature planted rubber
2	Blue	Land for mature planted rubber
3	Green	Land for coffee and pepper
4	Pink	Built-up area, water body
5	Purple	Paddy land

3.2.2. Supervised classification

Based on results of unsupervised classification, we conducted field surveys and examined reference map to create training samples. After sampling, the supervised method was used in the image classification process. The algorithm used in supervised classification was the Maximum Likelihood Classification (MLC). This method is commonly used to classify the objects that are heterogeneous, like industrial plants (Nguyen, Thanh Xuan, 1999). Results of classification are presented in Figure 3.

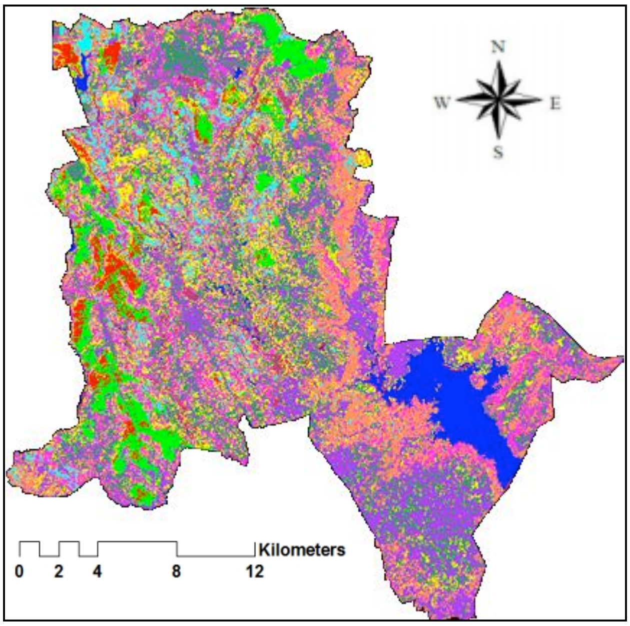

Figure 3. Result of supervised classification for band 654

3.2.3. Accuracy assessment of classified results

Before assessing the accuracy, classified results were compared with current state of land use/cover derived from statistics dated 01.01.2014. Land cover/use classes were divided as 5 main groups based on the purpose of the study (Table 5). It is shown that classified results from combination of band 654 give the best data that are approximate with statistics of land use/cover. Even though there are some differences in area of annual crops, perennial crops, and body water, the results could be accepted because of some following reasons. Firstly, due to spatial resolution of satellite image, it is difficult to identify small channel system for irrigating industrial crops such as pepper, coffee. Therefore, area of water body was interpreted lower than its real statistics, while area of perennial industrial crops and other land were interpreted higher than reality. Besides, the different in time of harvest could also affect the classified results. For example, some harvested paddy areas in the east of Chu Se district were misclassified as barren or built-up land. That is the reason why area of annual crops decreased while barren or built-up land increased in comparison with collected statistics. The land cover classification from supervised technique was evaluated in matrix table, which is used to determine Kappa statistic of each false colour combination thereafter. The results show that Kappa index under band 654 has the highest accuracy (0.975), followed by the combination of 543 spectral channels (0.917), and finally the combination of spectral channels 432 (0.915). Hence, classified result of band 654 indicates a good agreement between thematic maps generated from image and the reference data. In this case, we chose the interpreted result of band 654 to create thematic map for current perennial industrial crops in Chu Se District, Gia Lai Province.

Table 5. Results of classification

Type of land	**Reference (ha)**	**Band 432 (ha)**	**Band 543 (ha)**	**Band 654 (ha)**
Water body	4938.65	5948.73	3811.50	3266.82
Land of annual crop	16220.14	20983.20	9338.22	15459.66
Land of perennial crop	23616.79	15350.60	25264.20	24159.42
Forest land	11548.57	7250.49	11375.10	11739.69
Other land	7971.62	14526.50	14267.80	9438.39
Sum	**64295.77**	**64059.48**	**64056.78**	**64063.98**

Table 6. Accuracy of classified results

Band	Overall' accuracy	Kappa index	Ranking
Band 543	93.95 %	0.917	2
Band 654	98.16 %	0.975	1
Band 432	93.81 %	0.915	3

3.3. Mapping current state of perennial industrial crops

As stated above, classified result of band 654 was chosen for mapping current state of perennial industrial plants because of its high accuracy. By using ArcGIS 10.2 software, raster data was converted to vector data, moving from WGS 84 UTM coordinate system to VN2000 coordinate system. Consequently, current land use map of perennial industrial crops in 2014 at Chu Se District, Gia Lai Province was in accordance with national regulations (Ministry of Natural Resources and Environment, 2007). The established map of perennial industrial crops is presented in Figure 4.

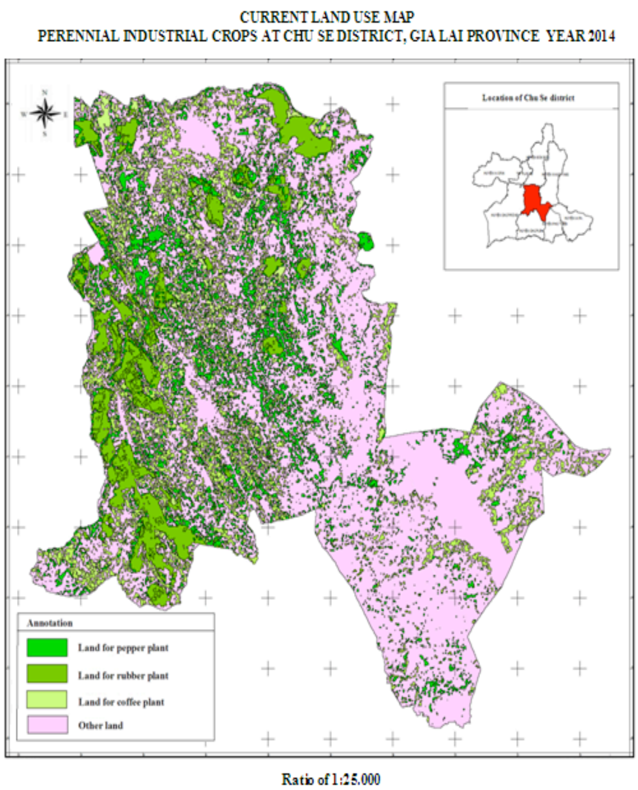

Figure 4. Current land use map of perennial industrial crops at Chu Se district, Gia Lai province

Based on the established map, area of perennial industrial crops in Chu Se District, Gia Lai Province were calculated and presented in Table 7. It is shown that area of coffee crops dominated the most in Chu Se District with 10680.12 ha, representing 16.67% of total area.

However, most of coffee areas were distributed scattered, just only two plantations with large area located at the corner of West - North and South - West of Chu Se District. Meanwhile, pepper crops were mainly grown around rubber crops and living areas with 7552.17 ha, representing 11.79%. There were over 5927.13 ha of rubber crops, representing 9.25% of total area in Chu Se District. Rubber plantations of rubber were mainly located in the west and north of Chu Se District.

Table 7. Statistics of land use for perennial industrial crops at Chu Se District in 2014

Land use type	**Area (ha)**	**Rate (%)**
Land for rubber plant	5927.13	9.25
Land for coffee plant	10680.12	16.67
Land for pepper plant	7552.17	11.79
Other land	39904.56	62.29
Total	**64063.98**	**100.00**

4. Conclusions

Building successfully land use map (1/25.000) of perennial industrial crops in Chu Se District, Gia Lai Province, Vietnam based on NDVI index derived from Landsat 8 OLI image. It showed that NDVI of perennial industrial crops ranged from 0.67 to 0.84. Based on classified results, land use of coffee, pepper and rubber crops were identified timely and accurately at 16.67%, 11.79% and 9.25% of total area, respectively.

The results of this research convey a realistic image of the real situation since it provides an overview of current land use of perennial industrial plants as well as changes in the area of crops not only for local officials but also other enterprises such as Vietnamese rubber companies. Hence, they will have appropriate and timely manner to maintain their growth, in order to increase the efficiency of the management of land resources and support the policy authorities getting appropriate and timely decisions.

Landsat 8 OLI satellite image at spatial resolution of 30m could not differentiate the object that is smaller than $900m^2$ in area. As can be seen, this kind of image is fit only to map the current land use/cover of district / town at ratio of 1/25.000 or less. However, it is effective resource because of its free approach, pure information, short iteration cycle acquisition (only 18 days), having ability to synchronize with the GIS software to edit the map as form of the user. The use of remote sensing and GIS technology also enables mapping the current state of multi-temporal land use.

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