The influence of satellite image spatial resolution on mapping land use/land cover: a case study of Ho Chi Minh City, Vietnam

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Abstract. Different spatial resolutions of optical satellite imagery provide different details in land use/land cover (LULC) mapping. Therefore, it is essential to decide the appropriate classification system for specific spatial resolution. This study used the same classification system to extract land use/land cover for District 2 and District 7 of Ho Chi Minh City, Vietnam in 2018 from two different spatial resolutions, Sentinel-2 (10 m) and VNREDSat-1 (2.5 m), images. Using the same set of ground truth data, the accuracy of the classified maps was assessed to select the right image for the study area corresponding to the given classification system. The outcomes revealed that both optical satellite images produced high overall accuracy (83% for Sentinel-2 images and 86% for VNREDSat-1 images) on the same classification system. It is easier to classify the cropland, grassland, roads, and industrial zones with VNREDSat-1 image whereas perennials, bare land, and aquaculture were easily classified with Sentinel-2 due to their homogeneity at a lower spatial resolution. This shows the importance of choosing the right spatial resolution following the requirements of the classification system.

1. Introduction

Nowadays, multi-spectral optical satellite images with various spatial resolutions have been applied in many fields, the most common application is to extract information about land cover and land use. Spatial resolution implies the smallest area on the ground that the sensor can detect. The higher the spatial resolution of the image, the smaller the pixel size is [1]. The basic information about the object on the satellite image strongly depends on the spatial resolution. Choosing the wrong spatial resolution can lead to wrong image classification. Figure 1 depicts that on the Sentinel-2 image, the pixels representing the urban area appear relatively homogeneous. However, observing at a higher spatial resolution, this area includes individual houses, roads, and plants. Increasing the spatial resolution of satellite images can lead to increased accuracy and provides a lot of useful information. However, the higher spatial resolution also introduces more confusion in classification, so choosing the right spatial resolution for the specific purpose will save time and money [1]. As more optical satellite images are made available, the selection of the appropriate spatial resolution plays an increasingly important role [2]. Free satellite images have medium to low spatial resolution like Sentinel-2, Landsat, and MODIS. These spatial resolutions cannot meet specific LULC classification requirements in complex areas such as urban areas [3-4], while high spatial resolution satellite imagery has the potential to greatly reduce the mixed-pixel problem [5]. However, the high spatial resolution imagery has other problems such as shadows of buildings and trees, inconsistencies in the urban area can make the incorrect classification.
This study aims to evaluate the effect of different spatial resolutions on the results of LULC classification. Specifically, the study used the same classification scheme for Sentinel-2 (10 m) and VNREDSat-1 (2.5 m) images acquired in 2018 for the study area, District 2 and District 7 of Ho Chi Minh City.

![Figure 1](image-url). An urban area from Sentinel-2 (a) and VNREDSat-1 (b) images.

2. Methodology
Figure 2 shows the study workflow, which includes satellite image data collection, pre-processing, LULC classification, accuracy assessment, and evaluation.

2.1. Study area
District 2 was established on April 1, 1997, located in the East of Ho Chi Minh City, with a total area of 5017 hectares. District 2’s topography has mounds and canals, accounts for 24.7% of the total natural area, with an average elevation of about 1.5 m to 3 m above sea level, with a slope of the North-South direction [6]. District 7 was established on April 1, 1997, located in the Southeast of Ho Chi Minh City, with a total area of 3,576 hectares. The terrain of District 7 is relatively flat, the topography does not change much, the average is 0.6 m to 1.5 m. The soil in District 7 is saline alum [7].

2.2. Data sets
The Sentinel-2 Multispectral Instrument (MSI) with four bands at 10 meters resolution and VNREDSat-1 with one panchromatic band at 2.5 meters and three bands at 10 meters were used to classify LULC. The Sentinel-2 data were acquired on March 24th, 2018 and November 4th, 2018, and VNREDSat-1 data were acquired on February 9th, 2018 and November 10th, 2018. The characteristics of both data sets are shown in Table 1 and Figure 3.
Figure 2. The whole flow chart of this research.

Figure 3. The study area (District 2 and District 7, Ho Chi Minh City, Viet Nam) and satellite images.
Table 1. Characteristics of the two satellite data sets used in this study.

| Image type       | Band          | Wavelength [nanometers] | Spatial resolution [meters] |
|------------------|---------------|-------------------------|-----------------------------|
| Sentinel-2 [8]   | Band 2 - Blue | 492.4                   | 10                          |
|                  | Band 3 - Green| 559.8                   | 10                          |
|                  | Band 4 - Red  | 664.6                   | 10                          |
|                  | Band 8 - NIR  | 832.8                   | 10                          |
| VNREDSat-1 [9]   | Panchromatic  | 450 – 750               | 2.5                         |
|                  | Band 1 (Blue) | 450 – 520               | 10                          |
|                  | Band 2 (Green)| 530 – 600               | 10                          |
|                  | Band 3 (Red)  | 620 – 690               | 10                          |
|                  | Band 4 (NIR)  | 760 – 890               | 10                          |

2.3. Classification methods

This study employed the Maximum Likelihood classification method, a popular method, and is considered as a standard algorithm for comparison with other algorithms [1]. The Maximum likelihood classifier considers that the radiometric values in each class fit a normal distribution. This allows each class to be described by a probability function from its mean vector and variance/covariance matrix. Hence, the probability that a radiometric value is a member of a given class can be calculated [10]. The training samples were selected distributing throughout the study area depending on the type of image. The classification results were then edited after the raw classification to increase the accuracy like: eliminate small areas, correct misclassified classes. The accuracy of classification results was evaluated by comparison with the match between ground data and classification classes. Ground data used to verify the accuracy of the classification were from field data and data collected from Google Earth. Information on the number of ground data and their locations is shown in Figures 3 and Table 2. For each classification result, a confusion matrix and the Kappa coefficient were calculated to determine overall accuracy and levels of misclassification for each land-use class.

Table 2. List of classification schemes.

| No. | Class name     | Number of ground data points |
|-----|----------------|------------------------------|
| 1   | Aquaculture    | 3                            |
| 2   | Bare land      | 7                            |
| 3   | Cropland       | 5                            |
| 4   | Industrial area| 10                           |
| 5   | Grassland      | 31                           |
| 6   | Perennials     | 14                           |
| 7   | Port           | 9                            |
| 8   | Roads          | 9                            |
| 9   | Urban          | 17                           |
| 10  | Water          | 5                            |
|     | Total          | 110                          |

2.4. Classification scheme

The land use/land cover classification scheme used in this study is listed in table 2. Those classes were based on MONRE’s regulation on land use status quo map (No. 22/2007/QĐ-BTNMT) modified for the purpose of the study. The major roads were classified into a separate class, while the smaller roads were considered components of land use parcels and could not be classified separately. The classes “ports”
and “industrial parks” were classified into separate classes due to the specific shapes of these objects in the images, while shrubs plants and unidentified plants were classified into "other".

3. Results and Discussion

3.1. Classification result
The classification results from Sentinel-2 and VNREDSat-1 images are shown in Figures 4 and 5. The result maps had a scale of 1:50 000. The most dominant class was urban areas, only a small area in District 2 still had cropland. Bare land and grassland in District 2 were more than those in District 7, concentrated mainly in the wards of An Phu, An Loi Dong, Thanh My Loi. The classification results also show the advantage of higher spatial resolution when the results from the VNREDSat-1 had more details when compared to the results from Sentinel-2 images.

3.2. Accuracy assessment
Sentinel-2 classified map achieved the overall accuracy of 83% and Kappa coefficient 0.80, while the VNREDSat-1 classified map achieved the overall accuracy of 86% and the Kappa coefficient 0.84. Table 4 and Table 5 are the confusion matrices of the classification result of Sentinel-2 and VNREDSat-1. VNREDSat-1 produced higher overall accuracy than Sentinel-2 due to its superior spatial resolution. This result showed that images with higher spatial resolution can produce classification results with higher overall accuracy, like the study of Chanida Suwanprasit and Naiyana Srichai [11]. The other two evaluations of classification maps are the producer's accuracy and user's accuracy. The producer’s accuracy measures how well a certain area has been classified. It includes the error of omission which refers to the proportion of observed features on the ground that are not classified on the map. The more omission error, the lower the producer’s accuracy. The user’s accuracy is a measure of the reliability of the map. It informs the user how well the map represents what is really on the ground [12].

Figure 4. The land use/land cover map of District 2 and District 7 in 2018 from Sentinel-2
When comparing the user’s accuracy of each land-use class, the result from Sentinel-2 data showed a high user’s accuracy for the port, cropland, grassland, water, and aquaculture. The urban class had the lowest user's accuracy (67%) and was easily confused with the industrial area because of the similarity in spectral reflectance. The remaining classes of Sentinel-2’s result had a high user's accuracy. The results from the VNREDSat-1 data showed a high user's accuracy for the ports, cropland, perennials, industrial area, and aquaculture. Considering the producer's accuracy, due to the high spatial resolution, the ports, grassland, urban, roads, industrial areas, and water surfaces were easily discriminated on the VNREDSat-1 data. Perennials and bare land were easily misclassified to grassland, similar to the aquaculture areas, where planted the aquatic plants as lotus could also be misclassified into another plant class.

Figure 6 shows the results of land use classification and the true color composite of the two satellite data, the industrial area of the Sentinel-2 image has spectral reflectance like urban areas. Therefore, the industrials area of Sentinel-2 data has a low producer's accuracy (60%). The result from the VNREDSat-1 data has more details of the road class than the Sentinel-2 data due to higher spatial resolution. The Sentinel-2 data acquisition was at the end of the crop season, so the cropland area had a spectral reflectance like bare land, but it was corrected after classification. Therefore, to classify with high accuracy requires the experience of the classifier in training samples as well as post-processing of raw classification.

Comparing the producer's accuracy of the two satellite data types, the ports, urban land, and water surface were easy to be classified. The VNREDSat-1 data had a higher producer's accuracy for cropland, grassland, roads, and industrial areas, suggesting that these classes need a high spatial resolution for identification. In contrast, the perennials, bare land, and aquaculture had a higher producer's accuracy.
from Sentinel-2 data, showing that these classes could be easily identified due to the homogeneity at the lower spatial resolution. Increasing the spatial resolution may cause difficulty in classification due to environmental complexity.

![Sentinel-2 and VNREDSat-1 comparison](image)

**Figure 6.** Quicklook and comparison of classification results in two areas using Sentinel-2 and VNREDSat-1.

**Table 3.** Confusion matrix of classification result from Sentinel-2 data.

| Reference data | Classified data | Total |
|----------------|-----------------|-------|
|                | Port            | Cropland | Grassland | Perennials | Bareland | Urban | Roads | Industrial area | Water | Aquaculture |     |
| Port           | 9               | 0        | 0         | 0          | 0        | 0     | 0     | 0               | 0     | 0           |     |
| Cropland       | 0               | 3        | 0         | 0          | 0        | 0     | 0     | 0               | 0     | 0           | 3   |
| Grassland      | 0               | 0        | 24        | 0          | 0        | 1     | 0     | 0               | 0     | 0           | 25  |
| Perennials     | 0               | 1        | 3         | 13         | 0        | 1     | 0     | 0               | 0     | 0           | 18  |
| Bare land      | 0               | 1        | 1         | 0          | 6        | 0     | 0     | 0               | 0     | 0           | 8   |
| Urban          | 0               | 0        | 2         | 1          | 16       | 0     | 4     | 0               | 0     | 0           | 24  |
| Roads          | 0               | 0        | 1         | 0          | 0        | 6     | 0     | 0               | 0     | 0           | 7   |
| Industrial area| 0               | 0        | 0         | 0          | 0        | 0     | 2     | 6               | 0     | 0           | 8   |
| Water          | 0               | 0        | 0         | 0          | 0        | 0     | 0     | 5               | 0     | 0           | 5   |
| Aquaculture    | 0               | 0        | 0         | 0          | 0        | 0     | 0     | 0               | 3     | 3           | 3   |
| Total          | 9               | 5        | 31        | 14         | 7        | 17    | 9     | 10              | 5     | 3           | 100 |

**Producer’s accuracy (%)**

- 100
- 60
- 77
- 93
- 86
- 94
- 67
- 60
- 100
- 100

**User’s accuracy (%)**

- 100
- 100
- 96
- 72
- 75
- 67
- 86
- 75
- 100
- 100
Table 4. Confusion matrix of classification result from VNREDSat-1 data.

| Reference data | Classified data | | | | Port | Cropland | Grassland | Perennials | Bare land | Urban | Roads | Industrial area | Water | Aquaculture | Total |
|----------------|-----------------|-----------------|-----------------|-----------------|---------------|---------|---------|---------------|---------|-------------|-------|
| Port           | 9               | 0               | 0               | 0               | 0             | 0       | 0       | 0             | 0       | 0           | 9     |
| Cropland       | 0               | 4               | 0               | 0               | 0             | 0       | 0       | 0             | 0       | 0           | 4     |
| Grassland      | 0               | 0               | 28              | 2               | 2             | 0       | 0       | 0             | 0       | 1           | 33    |
| Perennials     | 0               | 0               | 1               | 9               | 0             | 0       | 0       | 0             | 0       | 0           | 10    |
| Bare land      | 0               | 1               | 1               | 0               | 4             | 0       | 0       | 0             | 0       | 0           | 6     |
| Urban          | 0               | 0               | 1               | 1               | 16            | 0       | 0       | 0             | 0       | 0           | 19    |
| Roads          | 0               | 0               | 0               | 2               | 0             | 1       | 8       | 0             | 0       | 0           | 11    |
| Industrial area| 0               | 0               | 0               | 0               | 0             | 0       | 0       | 10            | 0       | 0           | 10    |
| Water          | 0               | 0               | 0               | 0               | 0             | 1       | 0       | 5             | 0       | 0           | 6     |
| Aquaculture    | 0               | 0               | 0               | 0               | 0             | 0       | 0       | 0             | 2       | 2           | 2     |
| Total          | 9               | 5               | 31              | 14              | 7             | 17      | 9       | 10            | 5       | 3           | 110   |
| Producer's accuracy (%) | 100 | 80 | 90 | 64 | 57 | 94 | 89 | 100 | 100 | 67 |
| User’s accuracy (%) | 100 | 100 | 84 | 90 | 67 | 84 | 73 | 100 | 83 | 100 |

4. Conclusion
The study classified LULC for Districts 2 and 7 of Ho Chi Minh City from two satellite datasets: Sentinel-2 (10 m) and VNREDSat-1 (2.5 m) using the same classification scheme. The results of the LULC classification had high overall accuracy and the Kappa coefficient showing the applicability of these data in the mapping. On the other hand, the results from the VNREDSat-1 data had the overall accuracy (86%) and the Kappa coefficient (0.84) higher than those from the Sentinel-2 data (overall accuracy: 83%, Kappa coefficient: 0.80). However, when considering the producer's accuracy and the user's accuracy, the cropland, grassland, roads, and industrial areas need data with a higher spatial resolution for classification. When it is necessary to classify at a low spatial resolution, it requires the experience of the classifier in post-classification to increase the user's accuracy. Perennials, bare land, and aquaculture were easy to classify despite having a lower spatial resolution. If high overall accuracy is required, then choosing satellite data with a higher spatial resolution will give better results. If it is necessary to classify specifically with each class, choosing the appropriate spatial resolution depends on the homogeneity of the object on the image. In this study, cropland, grassland, roads, and industrial areas need high spatial resolution. In contrast, perennials, bare land, and aquaculture require lower spatial resolution data to increase the homogeneity of the object.

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