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機械学習による Sentinel-2 および Landsat-8 画像の土地被覆分類比較：ベトナム・ラオカイ市を対象として

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Comparison Machine Learning-based Land Cover Classification Derived from Sentinel-2 and Landsat-8 Images: A Case Study in Lao Cai, Vietnam

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1. Introduction

A machine learning model Light Convolutional Neural Network (LCNN) has been successfully applied on Land Cover (LC) classification (Song *et al.*, 2019; Do *et al.*, 2020). Freely accessible Remote Sensing (RS) data such as Sentinel-2 and Landsat-8 has been widely used for mapping LC.

The multispectral Sentinel-2 is launched in 2015 which provides 13 spectral bands. Landsat-8 launched in 2013 includes 11 spectral bands. The two images are useful for agriculture, forestry and environmental monitoring. This study aims to compare the capability of the two RS data on LC classification for Lao Cai area in Vietnam.

2. Data and Methodology

2.1. Study area and data

The study area covering an area of approximately 525 km^2 is located in Lao Cai province in the North of Vietnam. Seven main LC categories of the area which are Water (W), Built-up (B), Mining/Bare land (MB), Rice Terrace (RT), Paddy Field (PF), Non-Forest Vegetation (NFV) and Forest (F) are classified in this research.

In this study, 4 bands at 10 m resolution (blue, green, red, NIR) of Sentinel-2 image captured on 3rd November 2018 and 6 bands at 30 m spatial resolution (blue, green, red, NIR, SWIR 1, SWIR 2) of Landsat-8 image obtained on 9th October 2014 covering the study area are distinguished for LC mapping. Reference polygon samples of the seven LC classes of the area are collected based on referring the samples used in Do *et al.* (2020) and visual interpretation of Sentinel-2 images with verification using Google Map.

The LCNN model employed in this study is as same as in Do *et al.* (2020). It includes 3 convolutional layers: The first layer with 20 filters of size $3 \times 3 \times n$, where n is number of input bands of the RS data, the second and third layers have 20 filters of size $2 \times 2 \times 20$. A Softmax layer is used for providing a probability distribution over 7 LC classes. Zero padding and stride equals 1 are employed. ReLU activation function and Adam optimizer with a learning rate of 10^{-5} are used. The number of epochs equals to 100, early stopping is applied. The LCNN model is implemented using Google Colaboratory framework. Finally, the classified LC maps extracted from the two RS data are evaluated and compared.

Comparison of training and validation for Sentinel-2 indicates drastic decreases in the first 10 epochs (Figure 1 (a)) and subsequently shows a slow decrease and remains steady value after 100 epochs. The loss for validation set fluctuates above loss for training set. Accuracy of training set increases in the first 10 epochs and subsequently almost stable. On the other hand, accuracy of validation set fluctuates below the values of training set (Figure 1 (b)). In case of Landsat-8, loss and accuracy for training and validation data are the similar to Sentinel-2 (Figure 1 (c) and (d)) but very little fluctuations observed for validation data is much less. The model terminates after 100 epochs. It is suggested that the model produces reliable results after 100 epochs.

3. Results

Figures 3(a) and 3(b) show the classified maps using Sentinel-2 and Landsat-8, respectively. Landsat-8 produces higher User's Accuracy (UA), Producer's Accuracy (PA) and Overall Accuracy (OA) for all LC classes, except PA value of water class (Figure 2). While Sentinel-2 image attains total OA value of 91%, Landsat-8 shows higher OA value of 97%.

OA of all LC classes of Landsat-8 are higher than 92%. RT and F are classified at the highest OA, at 98%. In contract, the OA values of Sentinel-2 are lower: NFV class is observed at the lowest accuracy, at 83%, while the highest accuracy is only 94% for B and F.

In general, higher resolution RS image could provide better LC classification result than lower resolution data. However, Korhonen *et al.* (2017) reported that the estimation accuracy of Landsat-8 is similar to Sentinel-2 (2017). This study also confirms that Landsat-8 image achieves better LC classification than Sentinel-2.

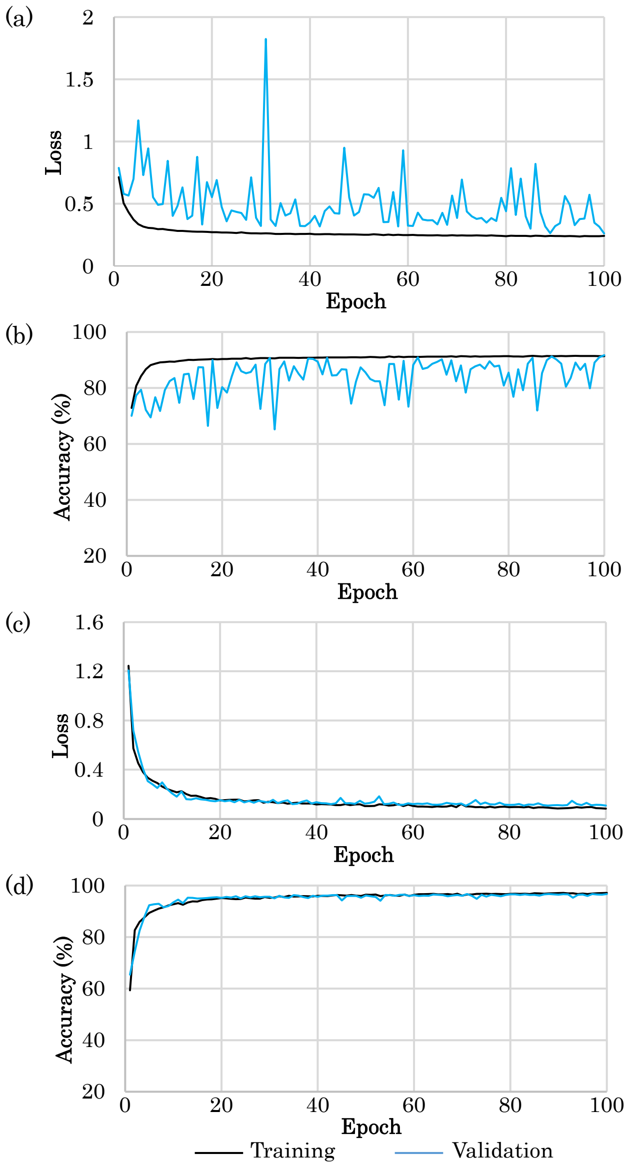

Figure 1: (a) Loss (b) Accuracy for Sentinel-2; (c) Loss (d) Accuracy for Landsat-8

Table 1. Classification accuracy

LC class	Accuracy (%)					
	Sentinel-2			Landsat-8		
	PA	UA	OA	PA	UA	OA
Water	98	76	86	94	97	95
Built-up	97	91	94	98	92	95
M/B	82	89	85	94	98	96
Paddy Field	81	91	86	93	96	95
Rice Terrace	90	94	92	100	96	98
NFV	83	83	83	96	88	92
Forest	95	94	94	98	99	98
Total OA		**91**			**97**	

UA: User's Accuracy, PA: Producer's Accuracy, OA: Overall Accuracy.

The reason for lower classification accuracy of Sentinel-2 could be due to fewer used spectral bands (4 bands) than Landsat-8 (6 bands). Moreover, the level LC details recorded at different resolutions could affect the classification accuracy. For example, Built-up class is the combination of road, building and factory sub-classes which are displayed at different spectral information in 10 m resolution Sentinel-2 image, leads to mixed-spectral in Built-up class, while at coarser resolution of 30 m Landsat-8 image, the sub-classes are shown at the same spectral detail. As a result, Landsat-8 provides better classification result over Sentinel-2.

The obtained results suggest that Landsat-8 image is more useful than Sentinel-2 on LC classification. Moreover, not only spatial resolution of RS images, but spectral bands selected and the level of details of LC classes could be important factors affect to LC classification result.

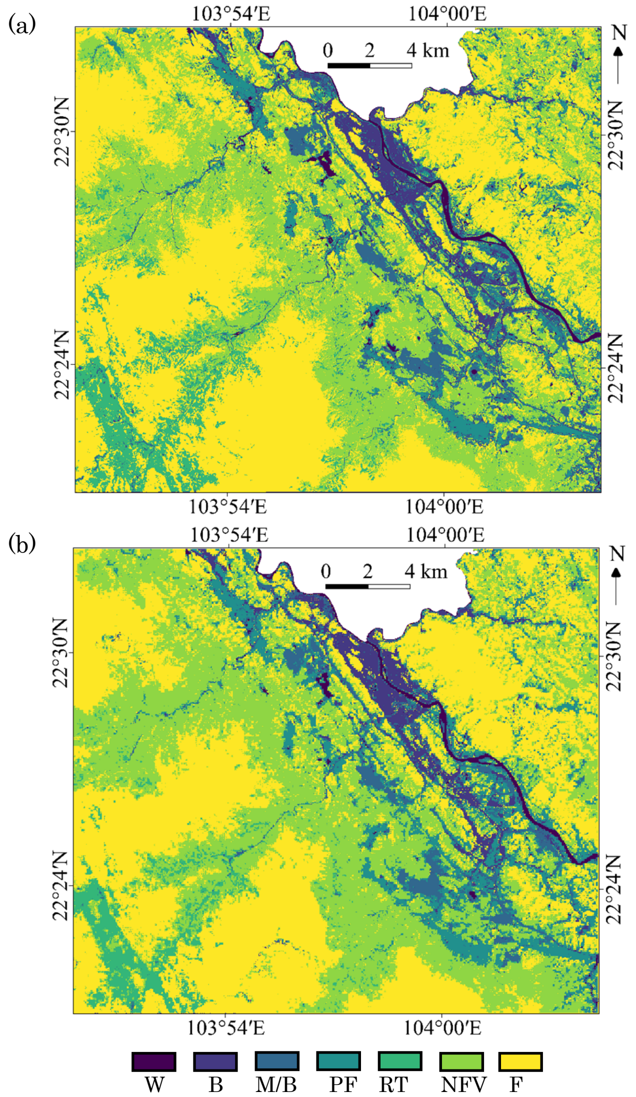

Figure 2: LC classification maps (a) Sentinel-2, (b) Landsat-8

Reference

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