Analysis of Natural Forest and Plantation Forest Changes in Vietnam Using Remote Sensing Data

(リモートセンシングデータを用いたベトナムの自然林と植林地の変化の分析)

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Abstract

Forest in Vietnam consists of 10.3 million ha of natural forests and 4.3 million ha of plantation forests (as of 2019), according to national statistics of the Vietnamese government. Since the 1990s, Vietnam has experienced a forest transition, in which net forest loss has been shifted to net forest gain. The main contribution of the reforestation in Vietnam was from the increase of plantation forest area which increased by more than 3.6 million ha from 1990 to 2020. However, deforestation in natural forests has been occurred, especially in Central Highlands of Vietnam with about 51,000 ha forest loss per year during 2010–2019, reported by the statistical data of Vietnamese government. The loss of natural forests has led to tremendous impacts, i.e., habitat fragmentation, changing water cycle, increasing carbon emission via conversion from forest to non-forest land-uses. To alleviate these issues, management and policies have been proposed and implemented from local to national scales. In such frameworks, the importance of highly detailed and accurate monitoring of the two forest types have been emphasized. To this end, this study provides a comprehensive solution comprising of mapping, change analysis, and investigating the causes of the changes of natural forests and plantation forests based on remote sensing data.

This study demonstrates a comprehensive and geographically transferable approach to produce a 12-category high-resolution land use/land cover (LULC) map over mainland Vietnam in 2016 by remote sensing data. The map included several natural forest categories (evergreen broadleaf, deciduous (mostly deciduous broadleaf), and coniferous (mostly evergreen coniferous)) and one category representing all popular plantation forests in Vietnam such as acacia (*Acacia mangium*, *Acacia auriculiformis*, *Acacia* hybrid), eucalyptus (*Eucalyptus globulus*), rubber (*Hevea brasiliensis*), and others. The approach combined the advantages of various sensor data by integrating their posterior probabilities resulting from applying a probabilistic classifier (comprised of kernel density estimation and Bayesian inference) to each datum

individually. By using different synthetic aperture radar (SAR) images (PALSAR-2/ScanSAR, PALSAR-2 mosaic, Sentinel-1), optical images (Sentinel-2, Landsat-8) and topography data (AW3D30), the resultant map achieved 85.6% for the overall accuracy. The major forest classes including evergreen broadleaf forests and plantation forests had a user's accuracy and producer's accuracy ranging from 86.0% to 95.3%. This study's map identified 9.55×10^6 ha ($\pm 0.16 \times 10^6$ ha) of natural forests and 3.89×10^6 ha ($\pm 0.11 \times 10^6$ ha) of plantation forests over mainland Vietnam, which were close to the Vietnamese government's statistics (with differences of less than 8%). This result provides a reliable input/reference to support forestry policy and land sciences in Vietnam.

Understanding deforestation is critically important for effective forest management, climate change mitigation, and biodiversity conservation. However, deforestation information from currently available forest data has limitations that reduce reliability and application. This study demonstrates an approach to deriving more accurate deforestation mapping based on high-resolution land use/land cover (LULC) maps. These LULC maps provide a means of distinguishing between natural forests and plantation forests over large spatial scales. Importantly, through this approach, deforestation of natural forests and the temporary loss of plantation forests can be effectively distinguished. In the deforestation hotspot in the Vietnam Central Highlands, the result show that the deforested area is closer to that reported in national statistics compared to other satellite-based datasets. In addition, I hypothesize a link between deforestation mean patch size (MPS) and the direct drivers of deforestation, including shifting agriculture and commodity-driven deforestation. That is, shifting agriculture-driven deforestation is likely to have smaller MPSs than commodity-driven deforestation across the entire country. Temporally, the regional mean deforestation MPS in Northern and Central Vietnam showed a steady increase during the period 2001–2019. In the Central Highlands, the regional mean deforestation MPS sharply increased between 2001 and 2010, and then decreased until 2019. Overall, the findings provide valuable reference information for developing and evaluating appropriate policy responses to deforestation.

Keywords: natural forest, plantation forest, remote sensing, Vietnam, acacia, eucalyptus, rubber, land use/land cover change, PALSAR-2, Sentinel, forestry policy, sustainable forest management, forest transition.