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SUMMARY OF DOCTORAL THESIS

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Title: SAR Data Application for the Smallholder's Oil Palm Plantation Management in Indonesia
(インドネシアにおける小規模オイルパーム農園管理のためのSARデータ活用手法の検討)

Expansion of oil palm plantation on low-land tropics has rapidly increased in response of high global demand for palm oil. Indonesia has become a major location of oil palm cultivation as it possesses favorable conditions supporting this activity. While it plays role as a vital economic strategy for the country, massive expansion in recent years has drawn criticisms for its potential of environmental damage and land use management problems. The involvement of independent smallholders in oil palm cultivation has caused even more uncontrollable expansion and land fragmentation since the cultivation is usually carried out in small patches area in random location. Moreover, decreasing availability of mineral soils has driven the expansion to the rich-carbon peatland area, which is principally less suitable for oil palms. Proper peat soil management, however, is still hardly applied by the smallholders, which lead to decrease in production. Addressing the problem regarding the uncontrolled oil palm expansion by independent smallholders, and the urgency of improvement and recovery for existed plantations on peatland, comprehensive study on the detection of distribution and tree conditions of smallholder's oil palm plantations are necessary for detail monitoring of small-scale plantation, as well as to support rehabilitation process, control, and implementation of best management practice. Synthetic Aperture Radar (SAR) data, which is notably favorable to overcome cloud cover in tropics, is mainly explored.

The main purpose of this study is to explore the methodology of ALOS PALSAR and ALOS PALSAR-2 application for identification and mapping of areal distribution and tree conditions of smallholder's oil palm plantations. In order to achieve this purpose, this study focused on the following specific objectives: (1) to explore the characteristic of oil palm plantation that can be identified by remote sensing data, (2) to examine the ability of dual and full polarization of ALOS PALSAR data in discriminating oil palms from other land cover types, (3) to identify the best integration methodology of ALOS-Sensor data to detect smallholder's oil palm plantations, (4) to investigate the most effective backscatter and polarimetric parameter for identifying oil palm tree conditions on peatland area.

Texture analysis is mainly applied as the methodology for classifying oil palm plantations and their tree conditions. Total of eight texture features of Gray Level Co-occurrence Matrix (GLCM) in 6 window sizes are tested and the most effective features and window size are selected to generate best combination for identifying oil palms. Land cover classification, as the general part to detect both area distribution and oil palm trees conditions, is performed using Maximum Likelihood Classifier (MLC). Support Vector Machine method was also used as alternative for detecting smallholder's oil palms using full polarization of ALOS PALSAR data.

The study on the detection of smallholder's oil palm plantations was carried out in Mesuji District of Lampung Province in Southern Sumatra, Indonesia, which is known as the development area of independent smallholder's oil palm. The smallholders in this area mainly cultivate the oil palm covering small area in random locations, which are surrounded by other land cover types. The result of this study revealed that the triangular planting pattern of oil palm plantation is the unique characteristic that can be interpreted in satellite image as distinct texture. Combination of mean and texture feature from dual

polarization ALOS PALSAR data was discovered as the most effective features to distinguish oil palms from other land covers. This is proved the ability of PALSAR data only for detecting oil palms. However, significant improvement in accuracy was achieved by integrating those data with multispectral AVNIR-2 image. The mean and variance extracted from HH, HV and HH-HV bands combined with all AVNIR-2 bands yielded in the best classification of mature oil palm with 92.45% of producer's accuracy and 66.67% of user's accuracy. While for the young oil palms, the producer's accuracy was 64.44% and the user's accuracy was 63.04%. The analysis for detecting smallholder' oil palms was also carried out using full polarization of ALOS PALSAR data which showed that the combination of four backscatter bands and 11 eigenvalue-eigenvector decomposition parameters resulted the best accuracy. It is also proved that classification using SVM resulted slightly better accuracy than using MLC method. Overall, detection using full polarization image might produce higher accuracy comparing to result of detection using dual polarization of PALSAR data only, however, it is still lower than the result achieved by using data integration of both PALSAR and AVNIR-2 image, which remarks the important of multispectral information for the classification.

The second study related to classification of smallholder's oil palm tree conditions was conducted in Pelalawan Regency of Riau Province, where the expansion of oil palm has been expanded to peatland area. In spite of the smallholders in this area generally own only slightly larger land than the first study area, plantations in this area are located close to each other. The methodology in this study was tested in 3 representative areas. Oil palm tree was classified in to three conditions, namely normal, replanted, and leaning trees. The classification using single texture feature in this study showed similar pattern with the previous one, which proved that mean feature has the greatest ability in detecting tree conditions, while 7 × 7 was the optimum window size. On the other hand, the analysis using PALSAR-2 parameters showed that even though the backscatter intensities are already effective to identify the normal palm trees, the other polarimetric parameters derived after decompositions are useful for identifying the standing condition of leaning oil palm trees. It is found that the 15 bands SAR parameter in 7 × 7 moving windows are the most combination for identifying tree conditions, by resulting 68.69% overall accuracy in area 1, 70.18%, and 72.75% for area 2 and 3, respectively.

The findings of the current study emphasize that the regular feature of oil palm planting patterns are the main characteristic and reason why the textural analysis become suitable for identification process. In this analysis, mean feature was constantly showed as the most significant GLCM feature, and can be directly applied for any further analysis related to oil palm classification. This study also proved that data integration derived from SAR and optical sensor will enrich the information and improve the classification accuracy. However, it is also revealed that whenever cloud-free image is not available, the identification of smallholder's oil palms and their tree conditions are still can be conducted using SAR data only. In this case, various polarimetric decompositions produced from the full polarization data are useful to provide more information of three-dimensional condition of tree standings, and therefore, detail analysis of identification of tree conditions are also possible. Finally, the distribution of smallholder's oil palm plantations map produced in this study, are hopefully can be useful for analyzing and predicting the expansion pattern by the smallholders, so that detail monitoring and policy making regarding to land management can be conducted to avoid more fragmented area. On the other hand, the tree condition maps on peatland area are hopefully will be useful as the guide for rehabilitation process to increase the yield and to encourage the application of best management practice by smallholders.

Keywords : Oil palm, smallholder, ALOS, PALSAR, PALSAR-2, polarimetric decomposition, texture analysis