HIGH-RESOLUTION SATELLITE REMOTE SENSING FOR ABOVEGROUND BIOMASS ESTIMATION OF TROPICAL RAINFORESTS AND OIL PALM PLANTATIONS IN SABAH

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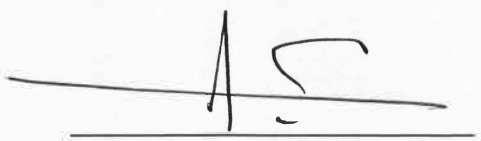

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ABSTRACT

The lack of research in the transition of reporting method in Reducing Emissions from Deforestation and Forest Degradation-plus (REDD+) program from using a low-resolution to high-resolution satellite image (HRSI) has led to this study. The approach of using geographical object-based image analysis (GEOBIA) towards the AGB quantification method is still not completely explored. The potential uses of HRSI in estimating the aboveground biomass (AGB) for two major land covers, oil palm plantations and tropical rainforests, in the middle of Sabah, East Malaysia was examined in this study. Field data collections to determine the AGB in oil palm plantation and forest reserve area were obtained through stratified random sampling method. Using HRSI, the effective spectral bands and vegetation indices were identified for segmentation and classification of objects where three kinds of useful information were extracted, that are spectral, geometrical and textural properties for modelling purposes. The AGB of oil palm plantation was estimated based on crown using a WorldView-2 image. A total of 222 samples of field-collected age-based data, AGB's regression towards the crown variables (crown diameter, crown area and crown perimeter) revealed the exponential nonlinear functions (R^2 of 0.80 ~ 0.85), which fulfil the lack of an allometric equation. Watershed technique was used to segment the oil palm crown at 4.8 % and 10.6 % of omission and commission errors. Due to overlaps in the oil palm's crown, age-based crown difference correction was implemented unto the detected crown. Among the crown variables, crown diameter was found to be the best in estimating the AGB for mature oil palm which improved from 62.9 $Mgha^{-1}$ (root-mean-square error (RMSE) 34.2 $Mgha^{-1}$) for detected crown to 122.5 $Mgha^{-1}$ (RMSE 16.4 $Mgha^{-1}$) for corrected crown; relative RMSE was 4.1 times lower after the correction. For crown area and crown perimeter, the relative RMSEs are both 1.8 times lower after the correction. On the other hand, AGB of the logged-over forest reserves were estimated using IKONOS-2 image based on two approaches; forest degradation classification and crown-based approach. Forest degradation classification approach utilised the spectral and textural information of forest surface roughness where else, a crown-based approach used the geometrical information from the crown. Forest degradation reduces AGB and alters forest canopy structure implicitly but

related. Modelling by restricting the complexities of forest surface roughness into respective forest degradation classes (very-degraded, degraded and intact forests) was implemented. Regression analyses confirmed the best independent variables for modelling the AGB are textural and spectral properties for each forest type. The estimated AGBs for very-degraded, degraded and intact forests are 73.6, 148.4 and 270.7 $Mgha^{-1}$ with RMSEs of 15.9, 38.9 and 18.7 $Mgha^{-1}$ respectively. A comparison with the classical non-classified forest approach (AGB = 126.1 $Mgha^{-1}$, RMSE = 64.1 $Mgha^{-1}$) approved the advantage of forest degradation classification approach. Meanwhile, the approach to use geometrical information from crown has underestimated the AGB by 19.4 % (AGB = 115.8 $Mgha^{-1}$, RMSE = 87.9 $Mgha^{-1}$) from field-based AGB. In using optical high-resolution satellite remote sensing data, forest degradation classification approach had greatly improved the widely reported saturation problem in AGB estimation, which normally occurred at high AGB density. As a conclusion, this study had extensively examined the use of crown shape and forest texture to estimate the AGB of oil palm plantation and tropical rainforest; two major competing land use in tropics.

ABSTRAK

SATELIT PENDERIAAN JAUH BERESOLUSI TINGGI DALAM PENGANGGARAN BIOMASSA ATAS-TANAH BAGI HUTAN HUJAN TROPIKA DAN PERLADANGAN KELAPA SAWIT DI SABAH

Penyelidikan yang masih kurang untuk melihat keberkesanan peralihan kaedah pelaporan di dalam program Reducing Emissions from Deforestation and Forest Degradation-plus (REDD+), daripada menggunakan imej satelit resolusi-rendah kepada imej satelit resolusi-tinggi (HRSI), telah mendorong kajian ini. Potensi penggunaan HRSI dalam penganggaran biomassa atas-tanah (AGB) bagi dua kelas tutupan tanah utama, perladangan kelapa sawit dan hutan hujan tropika, di pertengahan Sabah, Malaysia Timur telah diperiksa dalam kajian ini. Pengumpulan data lapangan untuk menentukan AGB di ladang kelapa sawit dan kawasan hutan simpan telah dilaksanakan melalui kaedah pensampelan rawak berstrata. Pendekatan "geographical object-based image analysis" (GEOBIA) terhadap kaedah pengkuantifikasian AGB masih belum diterokai sepenuhnya. Dengan menggunakan HRSI, 'band' spektrum serta indeks tumbuhan yang efektif telah dikenal pasti dalam pensegmenan dan pengkelasan objek di mana tiga jenis maklumat penting telah diekstrak iaitu sifat-sifat spektrum, geometri dan tekstur bagi tujuan pemodelan. AGB ladang kelapa sawit dikira berasaskan silara pokok menggunakan imej WorldView-2. Berasaskan 222 sampel data lapangan yang bersandarkan pada umur pokok, regresi AGB terhadap pembolehubah silara pokok (diameter silara, luas silara dan perimeter silara) telah merungkaikan fungsi eksponen tak-linear (R^2 dari 0.80 ~ 0.85), yang dapat mengisi masaalah ketiadaaan persamaan alometrik. Teknik "watershed" digunakan untuk mensegmen silara kelapa sawit pada 4.8 % ralat terabai dan 10.6 % ralat terlebih-buat. Disebabkan masalah pertindihan silara pokok maka pembetulan beza silara bersandarkan umur telah dilaksanakan ke atas silara yang disegmen. Di antara semua pembolehubah silara, diameter silara adalah didapati paling berkesan dalam menganggarkan AGB bagi kelapa sawit matang yang mana menunjukkan penambahbaikan daripada 62.9 $Mgha^{-1}$ (ralat punca-purata- kuasa-dua (RMSE) 34.2 $Mgha^{-1}$) untuk silara yang disegmen kepada 122.5 $Mgha^{-1}$ (RMSE 16.4 $Mgha^{-1}$) untuk silara telah diperbetulkan; RMSE relatif adalah 4.1 kali lebih rendah selepas pembetulan. Untuk luas silara dan perimeter silara,

RMSE relatif bagi kedua-dua pembolehubah adalah masing-masing 1.8 kali lebih rendah selepas pembetulan. Sebaliknya, AGB bagi hutan simpan pernah-balak telah dianggar dengan menggunakan imej IKONOS-2 melalui dua pendekatan; kaedah pengkelasan degradasi hutan dan kaedah berasaskan silara pokok. Kaedah pengkelasan degradasi hutan menggunakan informasi spektrum dan tekstur "forest surface roughness" manakala kaedah berasaskan silara pokok menggunakan informasi geometri dari silara. Degradasi hutan mengurangkan AGB dan mengubah struktur kanopi hutan secara tersirat tetapi berkait. Pemodelan dengan mengehadkan kerumitan "forest surface roughness" kepada beberapa kelas degradasi hutan (hutan belukar, hutan muda dan hutan tebal) telah dilaksanakan. Analisa regresi untuk setiap jenis hutan telah mengesahkan bahawa pembolehubah tak-bersandar yang terbaik untuk memodelkan AGB adalah daripada sifat tekstur dan spektrum. Anggaran AGB untuk hutan belukar, hutan muda dan hutan tebal adalah 73.6, 148.4 dan 270.7 Mgha^{-1} dengan RMSE masing-masing ialah 15.9, 38.9 dan 18.7 Mgha^{-1}. Perbandingan dengan kaedah klasik iaitu hutan tanpa pengkelasan (AGB = 126.1 Mgha^{-1}, RMSE = 64.1 Mgha^{-1}) telah menyokong bahawa kelebihan adalah terletak pada kaedah pengkelasan degradasi hutan. Sementara itu, pendekatan yang menggunakan informasi geometri dari silara pokok telah teranggar-rendah AGB sebanyak 19.4 % (AGB = 115.8 Mgha^{-1}, RMSE = 87.9 Mgha^{-1}) daripada AGB sebenar di lapangan. Melalui penggunaan data beresolusi tinggi satelit optik penderiaan jauh, pendekatan melalui pengkelasan degradasi hutan telah memperbaiki masalah ketepuan yang dilaporkan secara meluas dalam penganggaran AGB yang biasa berlaku pada kepadatan AGB tinggi. Kesimpulannya, kajian ini telah memeriksa secara mendalam penggunaan informasi sifat bentuk silara pokok dan tekstur hutan dalam penganggaran AGB ladang kelapa sawit dan hutan hujan tropika; dua pesaing utama penggunaan tanah di kawasan tropika.

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