Effects of Forest Disturbances on Forest Structural Parameters Retrieval from Lidar Waveform Data

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ABSTRACT

The effect of forest disturbance on the lidar waveform and the forest biomass estimation was demonstrated by model simulation. The results show that the correlation between stand biomass and the lidar waveform indices changes when the stand spatial structure changes due to disturbances rather than the natural succession. This has to be considered in developing algorithms for regional or global mapping of biomass from lidar waveform data.

***Index Terms*—** lidar waveform, forest, disturbance, biomass

1. INTRODUCTION

Large-footprint lidar systems have been developed to provide high-resolution, geo-located measurements of vegetation vertical structure and ground elevations beneath dense canopies. Over the past decade, several airborne and space-borne large-footprint lidar systems have been used to make measurements of vegetation. The lidar waveform signature from large-footprint lidar instruments, such as the Laser Vegetation Imaging Sensor (LVIS) [1] has been successfully used to estimate the tree height and forest above-ground biomass [2-6].

One of the objectives of the NASA DESDynI (Deformation, Ecosystem Structure and Dynamics of Ice) Mission is to characterize terrestrial ecosystems with respect to biomass, biodiversity, and disturbance/change through time. Forest degradation, which was defined by the UNFCCC (COP-13) as any forest that has experienced a loss, is an important aspect of forest disturbance. Accurate estimation of the amount and the changes of above-ground biomass are important for monitoring forest degradation. DESDynI utilizes both lidar and radar to characterize forest 3-D structure and intents to provide accurate estimates of global biomass. Forest biomass is not a direct measurement of the remote sensor. The direct measurement of lidar is the vertical profile of reflecting material within a canopy. Because the vertical distribution of canopy is correlated with biomass, so the lidar waveform can be used to estimate biomass. On the other hand, the correlation between canopy vertical structure and biomass may change with the forest type, spatial structure changes due to disturbances, etc. In this study, the effect of forest disturbances on lidar waveform and the biomass retrieval model is investigated using theoretical model and lidar waveform data.

2. STUDY SITE AND DATA

The test site for this project is the mixed hardwood and softwood forest of Northern Experimental Forest (NEF), Howland, Maine (45°15'N, 68°45'W). The forests consist of undisturbed near-mature forest, and forests with early clear cuts, strip cuts, and recent selective cuts (see Fig. 1). These forest management approaches reduce the biomass, and have different effects on canopy heights. For example, selective harvesting may remove a significant proportion of the biomass without drastically changing the top canopy height.
The location, diameter at breast height (dbh) and species for every tree with a dbh greater than 3 cm in a 200m by 150m area was recorded in 1989 and again in 2003. This site and surrounding forests have been preserved for research purposes. In 2006, a 50m by 50m stem map was measured in an area with selective cut.

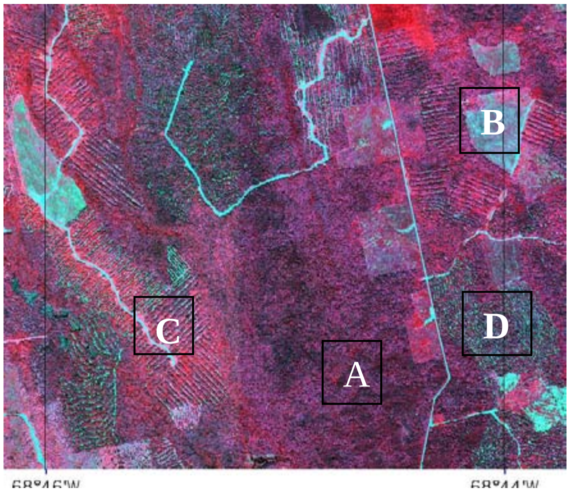

Fig. 1. IKONOS image showing undisturbed forests (A) and those with the clear cut (B), strip cut (C) and selective cut (D).

3. METHODS AND RESULTS

A lidar waveform model was used to simulate the effects of various forest management practices on the lidar waveform. The forest stands simulated from a forest growth model were used as original, un-disturbed stands. The strip-cut and select-cut were applied to these stands to simulate the forest harvesting practice in this area. Fig. 2 shows a 200-year forest stand and after the cuts. The left figure shows the tree distribution of the original stands. The center figure shows the strip-cut pattern. All tress were removed from the shaded area, and the cleared areas then filled in with the trees from a 10-year stand, simulation the clear cut happedn 10 years ago. The right figure shows the pattern after selective cut. One third of large trees (DBH greater than 25 cm) were randomly removed from the original stand.

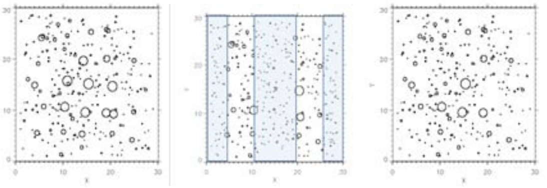

Fig. 2. From left to right: stands of original, strip-cut and selective-cut.

Fig. 3 shows the lidar waveforms of a stand before and after the disturbances from LVIS data and simulated using a 3D lidar waveform model [7]. The left figure shows the LVIS waveforms. The blue line is a waveform from the un-disturbed area A and the red line is a waveform from the disturbed area B. The top canopy height didn't change much after the disturbance. The energy from canopy was reduced. Because of the opening of the canopy, the energy returned from ground surface increased. The simulated waveforms in the figure at right show the same changes.

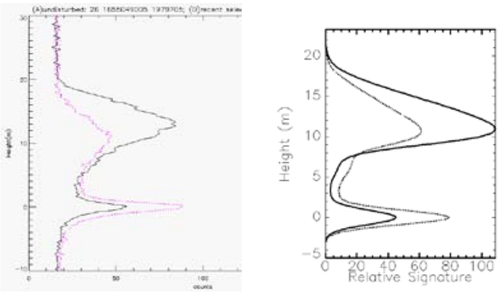

Fig. 3. Left – LVIS waveforms from undisturbed area A and the area D with the selective cut (red); Right – simulated waveforms: original stands (solid) and after selective cut (dash line).

Forest stands with ages from 5 to 500 years were simulated using a forest growth model as the black dots shown in Fig. 4. The disturbances were applied to the stands with ages from 80 to 500 years. The red and green symbols show the biomass of the stands after the disturbance. The lidar waveforms of these stands were simulated, and waveform indices were calculated. Studies have shown that the rH50, i.e. the height within the waveform where the waveform energy is equally divided above and below the line, is highly correlated to stand biomass [5]. Fig.5 shows the relation of rH50 and biomass for stands with and without disturbances.

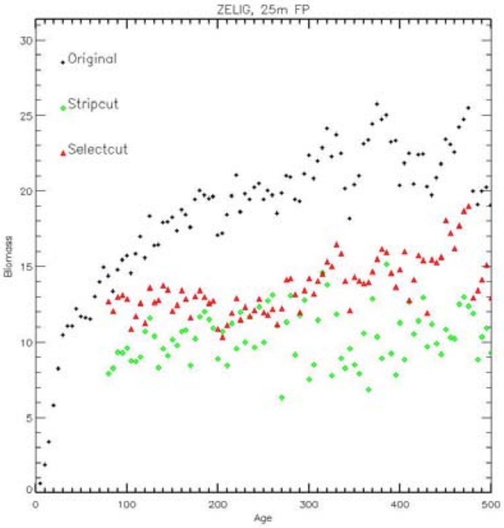

Fig. 4. Biomass of the forest stands of ages from 5 to 500 years (black dots) simulated using forest growth model. The red and green symbols show the biomass of disturbed stands.

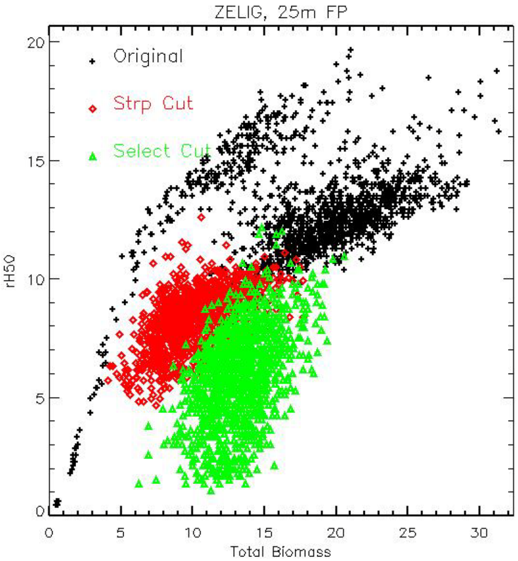

Fig. 5. The relation between rH50 and biomass changes when the structure of the stand changes. The black dots represent original stands. The red and green symbols are stands after disturbances.

Because of the changes shown in Fig. 5, the models for predicting biomass from lidar waveform indices will be different for forests with significantly different spatial structures. From Fig. 5, it seems that there are two groups in the original stands. One includes the stands from very young age to about 200 years. For this group, both rH50 and biomass increase with age. When the stands reach ages ~150-200 years, big trees start to die randomly in the model, creating the similar structure as those disturbed stands.

Fig. 6 shows the comparison of biomass predicted from lidar waveform indices and those calculated from input data to the lidar waveform model for original stands. The error is 2.26 Kg/m2 or 22.6 Mt/ha. The error calculated here is the root mean of the square of the difference between predicted biomass, not the RMSE from regression (also shown in the figures). The error becomes larger when the stands get older. When the stands with ages from 5 to 200 years used, the prediction accuracy improves as shown in Fig. 7.

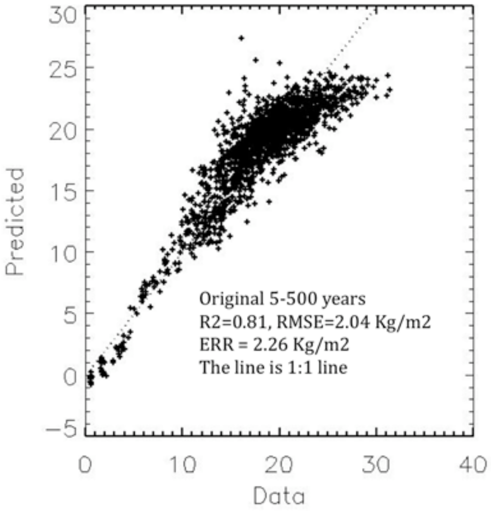

Fig. 6. Predicted biomass vs data for all original stands.

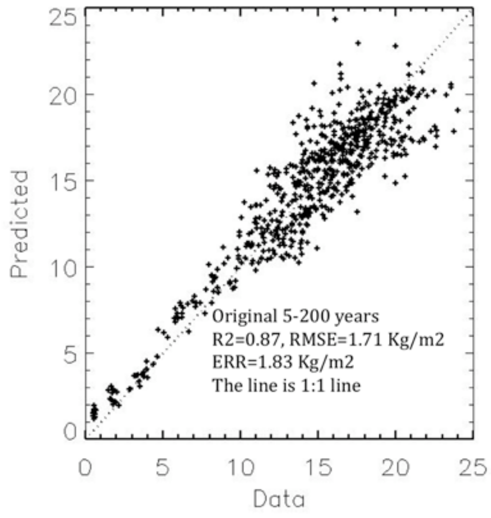

Fig. 7. Predicted biomass vs data for original stands with ages 5 to 200 years.

The Fig. 8 shows the biomass estimation results for strip-cut stands. By using its own prediction model, the accuracy is better.

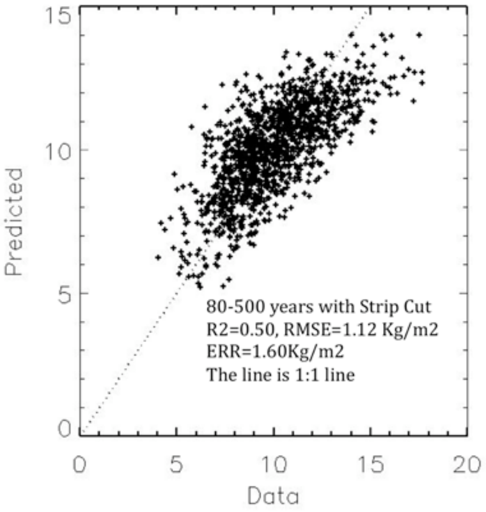

Fig. 8. Predicted biomass vs data for stands of strip cut.

4. CONCLUSION

The results from this study using lidar waveform model indicate that the structure changes caused by forest disturbance need to be considered in developing algorithms for regional biomass mapping from lidar waveform data. This needs to be further verified using field data, which will be conducted in near future.

8. REFERENCES

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