EVALUATION FOR DAMAGED DEGREE OF VEGETATION BY FOREST FIRE USING LIDAR AND DIGITAL AERIAL PHOTOGRAPH

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ABSTRACT: The LiDAR data structure has the potential for modeling in three dimensions because the LiDAR data can represent voxels with *z* value under certain defined conditions. Therefore, it is possible to classify the physical damaged degree of vegetation by forest fire as using the LiDAR data because the physical loss of canopy height and width by forest fire can be relative to an amount of points reached to the ground through the canopy of damaged forest. On the other hand, biological damage of vegetation by forest fire can be explained using the NDVI (Normalized Difference Vegetation Index) which show vegetation vitality. In this study, we graded the damaged degree of vegetation by forest fire in Yangyang-Gun of South Korea using the LiDAR data for physical grading and digital aerial photograph including Red, Green, Blue and Near Infra-Red bands for biological grading. The LiDAR data was classified into 2 classes, of which one was Serious Physical Damaged (SPD) and the other was Light Physical Damaged (LPD) area. The NDVI was also classified into 2 classes which are Serious Biological Damaged (SBD) and Light Biological Damaged (LBD) area respectively. With each 2 classes of the LiDAR data and NDVI, the damaged area by forest fire was graded into 4 degrees like damaged class 1, 2, 3 and 4 grade. As a result of this study, 1 graded area was the broadest and next was the 3 grade. With this result, we could know that the burned area by forest fire in Yangyang-Gun was damaged rather biologically because the NDVI in 1 and 3 grade appeared low value whereas the LiDAR data in 1 and 3 grade included light physical damage like the LPD.

KEY WORDS: Forest fire, LiDAR, NDVI, Point density

1. INTRODUCTION

It is important to determine fire behavior for prospecting moving direction of forest fire and preventing serious damage. Previous researches for forest fire were almost for modeling fire behavior and estimating fuel parameters (Rianõ *et al.*, 2003; Andersen *et al.*, 2005). In South Korea, especially, studies for forest fire were only for modeling occurrence probability of forest fire by topographical and spatial characteristic (An *et al*, 2004; An *et al*, 2005). However, after forest fire occurs, the evaluation of damaged area by forest fire is necessary for devising restoration plans of forest. But such a study to grade damaged degree after the forest fire has been rarely performed in South Korea.

For modeling fire behavior and estimating forest fuel parameter, in previous studies, aerial photograph and extensive fieldwork have been the traditional tools (Oswald *et al.*, 1999). However, recently, broad information for forest area can be acquired since satellite remote sensing technique develops. Therefore, detecting and modeling forest-fired areas are more efficient and operative than traditional aerial photograph or fieldwork. However, a serious problem of such remote sensing using passive sensor system is that it can not describe the amount of the canopy fuel and forest parameters from forest structure because it doesn't have the elevation information by itself. On the other hand, Light Detection and Ranging (LiDAR) with active sensor system, especially, has recently been used to extract surface information, as it can acquire highly accurate object shape characteristics using geo-registered 3D-points (Kwak *et al.*, 2006). Therefore, the LiDAR system can measure both vertical and horizontal forest structures in forested areas, such as tree heights, sub-canopy topographies and distributions, with high precision (Holmgren *et al.*, 2003). Thud, recently, LiDAR is used to model fire behavior and estimate forest fuel parameters which need tree volume and structure information (Rianõ *et al.*, 2003; Rianõ *et al.*, 2004, Andersen *et al.*, 2005).

In this paper, with such characteristic of the LiDAR we could evaluate the damaged area by forest fire as grading the damage. Moreover, we also used a Near Infra-Red (NIR) aerial photograph for evaluating biological damage because LiDAR had the only physical information of burned area. Through the both data, the damaged area was classified into four grades as evaluated with serious or light biological and physical damage. Afterward, we verified the accuracy of classification using true-colored and NIR aerial photograph with the naked eye.

2. STUDY AREA

The study area for this study is located in the Yangyang-Gun, which is in North East of South Korea (Figure 1). The latitude range of Yangyang-Gun is between 37°51′34″N to 38°10′41″N, and the longitude range is between 128°22′26″E to 128°55′47″E. The total area of Yangyang-Gun is 628.60 km² – 535.20 km² (85%) for forest, 58.6 km² (9%) for agriculture, and 34.8 km² (6%) for another land uses. The some part of Yangyang-Gun is mountainous area; about 74% of total area is distributed within 100 to 1,360 meters above sea level. The forest area is composed of *Pinus koraiensis* (Korean Pine) mainly. Approximately 315 ha of whole area were selected for this study. Among the area, we extracted only forested area (approximately 116 ha) and classified into 4 grades.

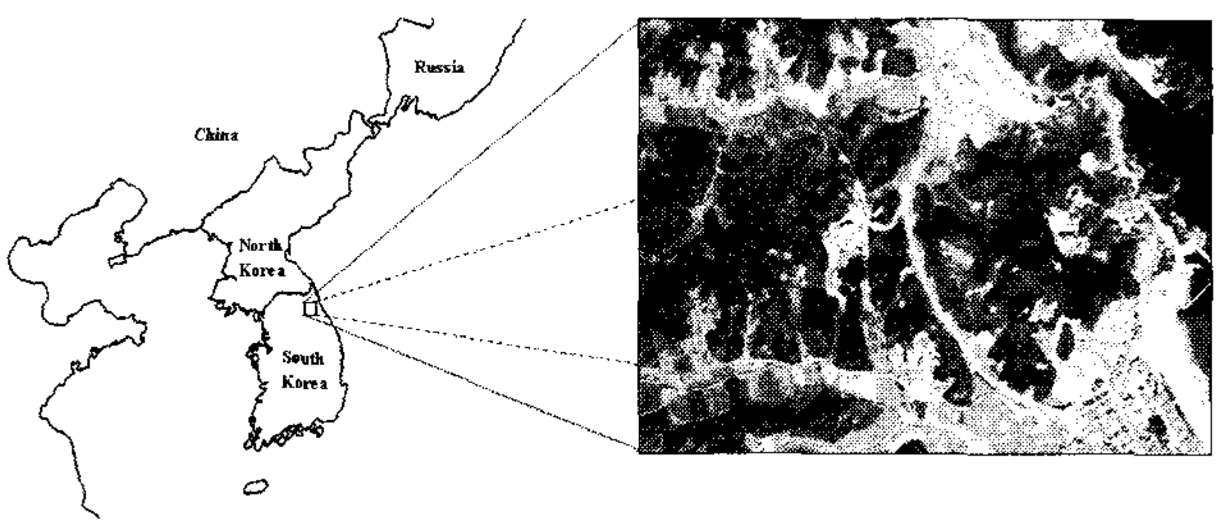

Figure 1. Location of study area

3. MATERIALS

3.1 LiDAR Data

In this paper, Optech ALTM 3070 (a small footprint LiDAR system) was used for acquisition of the LiDAR data, with the flight performed on 6th April 2005 which was the next day of enormous Yangyang-Gun forest fire disaster arisen. The study area was measured from an altitude of 1,000m, with a sampling density of 1.27 points per square meter, and the radiometric resolution, scan frequency and scan width were 12bits, 70Hz and ±25°, respectively. In order to calculate ground returns ratio, LiDAR data was classified into 2 groups with MicroStation 8.1 and TerraScan Program; Ground Return (GR) and Total Returns (TR). GR is the reflectance value on the ground and was generated by the algorithm of TerraScan Program.

3.2 Digital Aerial Photograph

A digital aerial photograph with red, green and blue bands was acquired simultaneously with LiDAR data. On the other hand, a NIR digital aerial photograph was obtained separately with LiDAR data and RGB digital aerial photograph because the special lens was needed for acquisition of NIR band. The spatial resolution of RGB and NIR digital aerial photograph is 0.7 x 0.7 meter. The NDVI used in this paper was calculated by the red band and NIR band with ArcGIS 9.0 Program.

4. METHODS

4.1 Calculation of Ground Returns Ratio

The LiDAR has the potential for obtaining geo-registered 3D-points whereas satellite imagery and aerial photograph are difficult to extract the 3 dimensional information of forested area (Kwak *et al.*, 2006). Moreover, the laser is similar to the sunlight at the aspect based on reflectance or transmission through the canopy (Kwak *et al.*, 2007). Therefore, we can estimate the ground returns ratio as acquiring the 3D points reflected on the canopy and the ground in forested area.

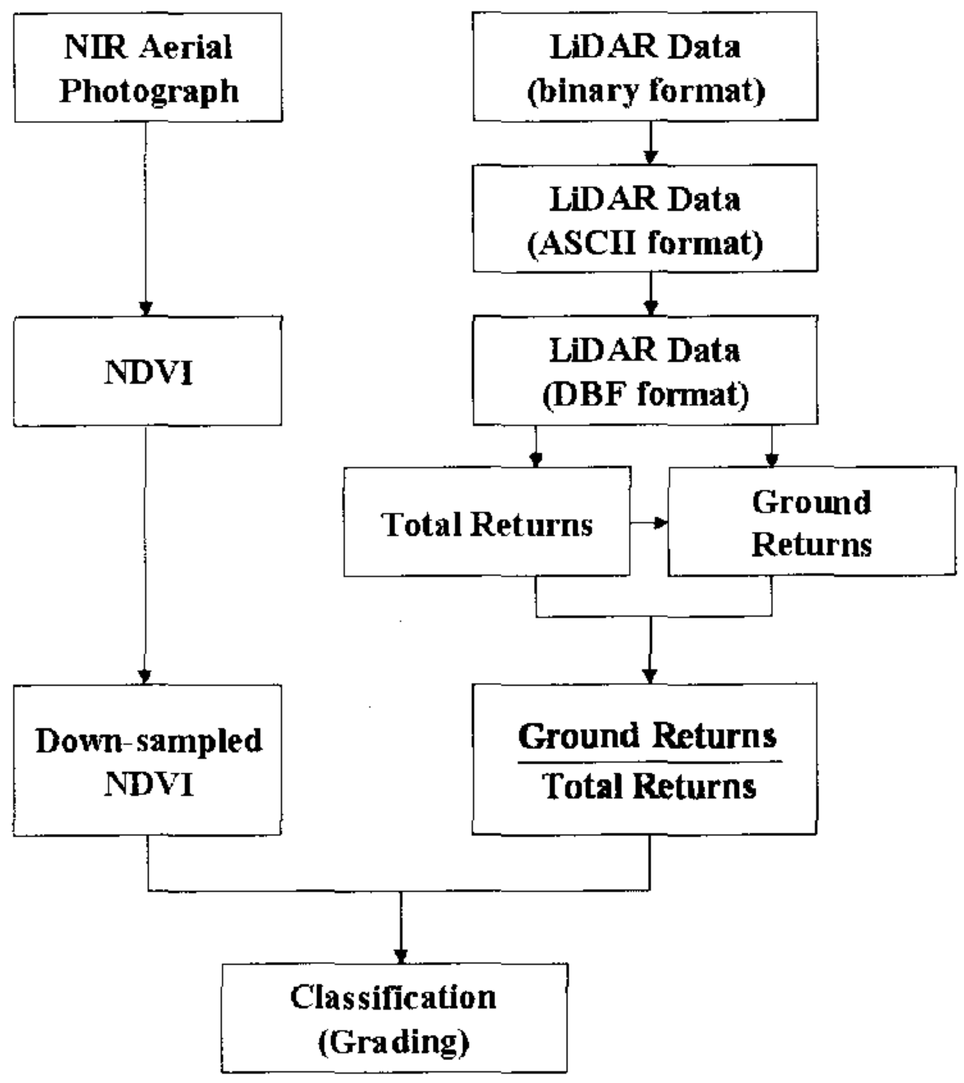

Figure 2. Analysis process of damaged area

With above concept, we assumed that ground returns ratio in serious damaged area by forest fire might be larger than those in light damaged area. If one area was rarely damaged by forest fire, laser pulses from an aircraft might be more intercepted by the canopy. On the other hand, if the area was damaged seriously, the ground returns ratio might be larger than those in light damaged area. Therefore, physical damaged degree could be estimated with the ground returns ratio.

For calculating ground returns ratio, two point clusters are required - one is the number of ground returns and the other is the number of total returns in the study area. The number of ground returns can be generated by the algorithm of TerraScan Program which classifies the ground returns as selecting the optimal points with such setting factors as initial points, terrain angle, iteration angle and iteration distance. The number of total returns can be clustered simply with whole points which were the sum of reflected returns through the canopy and on the ground. The number of ground and total returns were created by the number of points within 10m x 10m virtual window respectively. Finally, the number of ground and total returns was converted to raster data whose spatial resolution was 10m x 10m. With the raster data generated, ground returns ratio was calculated as following equation 1.

$$ground\ returns\ ratio = \frac{No.\ of\ ground\ returns}{No.\ of\ total\ returns} \quad (1)$$

4.2 Calculation of NDVI

NDVI calculated from digital aerial photograph was used to estimate the biological damage degree which could not be taken from LiDAR data. Proposed by Rouse *et al.* (1973), NDVI was originally used to locate vegetation in Great Plains. Live green plants appear relatively dark in the visible and relatively bright in the near-infrared (Gates, 1980). Therefore, in this study, NDVI was adopted to represent the health of forested area after the occurrence of forest fire.

$$NDVI = \frac{InfraRed - Red}{InfraRed + Red} \quad (2)$$

5. RESULTS AND DISCUSSIONS

5.1 Classification of Ground Returns Ratio and NDVI

For classifying damaged area, the classification of the ground returns ratio and NDVI must be performed respectively before fusing the both to grade damaged degree. Therefore, we classified ground returns ratio into 2 grades, serious physical damage and light physical damage.

Figure 3. Classification of ground returns ratio into 2 grades, serious and light physical damage area (Black and white are serious and light physical damage respectively)

The criterion of classification was determined by the Jenks' natural break method. Jenks' natural breaks classification determines the best arrangement of values into classes by comparing the sum of squared differences of values from the means of their classes (ESRI, 2004). When Jenk's natural break classification was used in this study, we could obtain optimal criterion with the smallest variation in each class.

NDVI was also classified into 2 grades, serious biological damage and light biological damage. The criterion to decide aliveness or death of vegetation by forest fire was assumed as NDVI value zero because NDVI ≤ 0 represents non-living thing like water and NDVI ≥ 0 describes living thing like vegetation of land (McConnachie *et al.*, 2002).

Figure 4. Classification of NDVI into 2 grades, serious and light biological damage area (Black and white are serious and light biological damage respectively)

5.2 Grade of Damaged Area

Both raster data classified were fused into one raster data for grading damaged area into 4 groups. Grading was carried out as the multiplication of ground returns ratio and NDVI. As a result, the area which was evaluated as serious physical damage (SPD) and serious biological damage (SBD) was determined to the 1st grade. The 2nd grade was determined to the area which was evaluated as serious physical damage (SPD) and light biological damage (LBD). The 3rd grade was determined with the area which was evaluated as light physical damage (LPD) and serious biological damage (SBD). At last, the 4th grade was fixed with the area which was evaluated as light physical damage (LPD) and light biological damage (LBD).

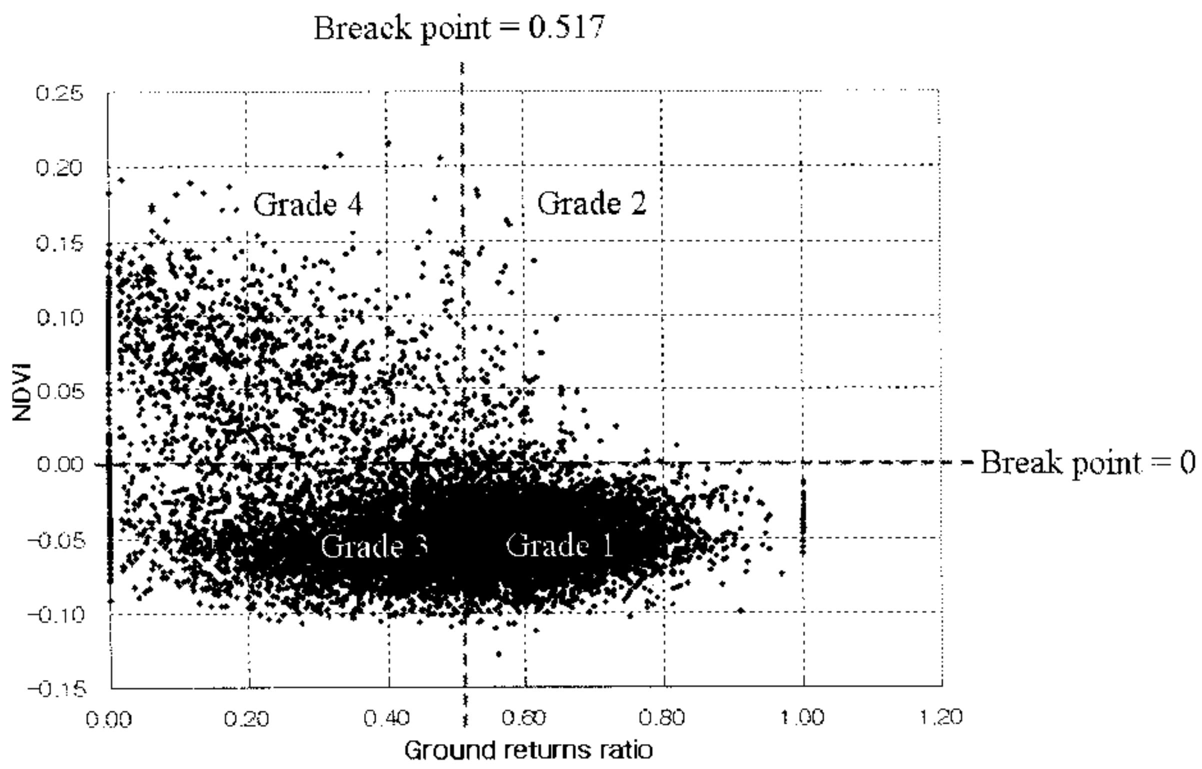

Figure 5. Grade by Range of NDVI and ground returns ratio

As a result, the 1st, 2nd, 3rd and 4th grade area were 75.66 ha (65.21%), 2.92 ha (2.52%), 26.04 ha (22.44%) and 11.40 ha (9.83%) respectively.

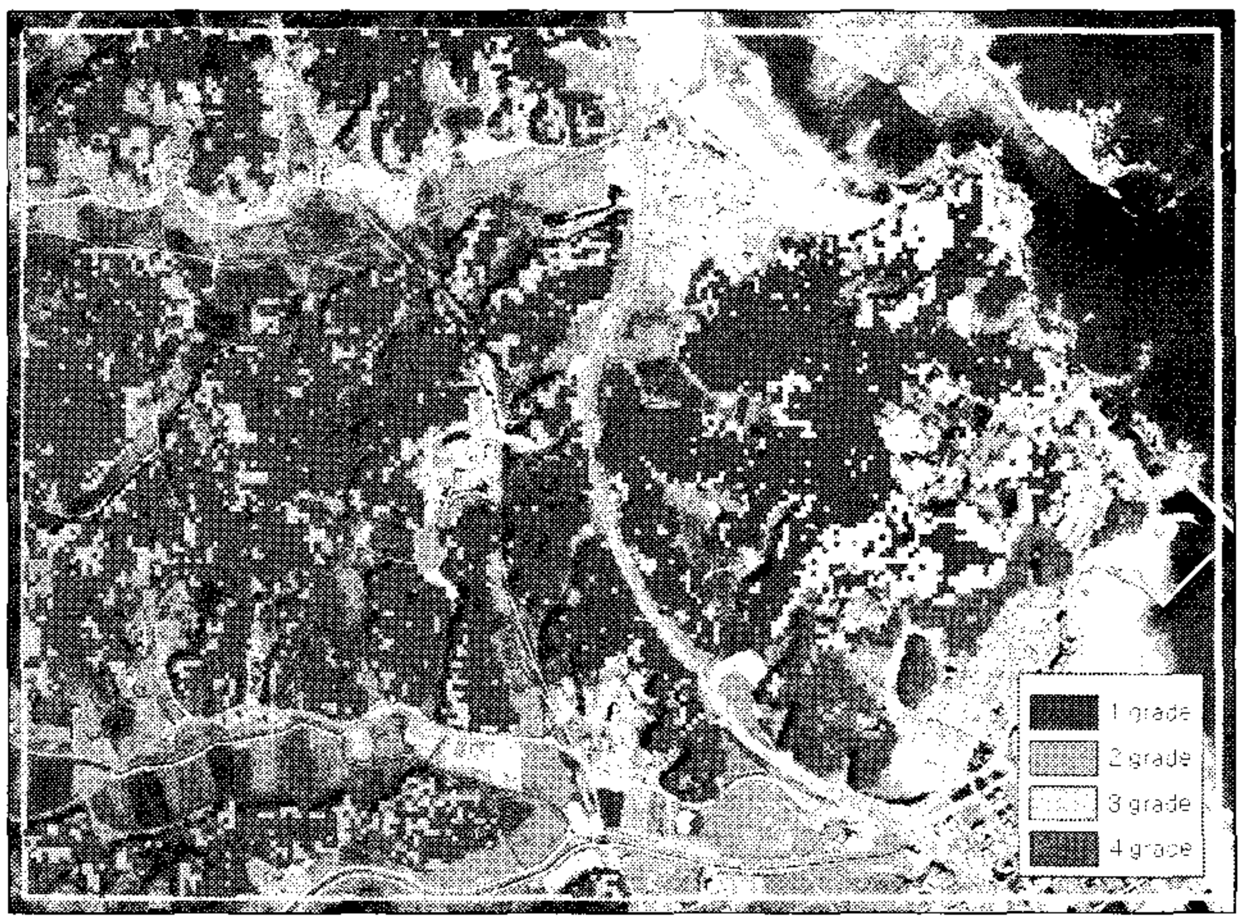

Figure 6. Grading of damaged area by forest fire

In this study, when the grading was performed, we used only forested area boundary in study area because non-forested area caused classification errors; e.g., the paved roads might be classified into serious damaged area even if the place had been not burned, on the other side, the house roofs might be classified erroneously into light damaged area because they couldn't help having the only first returns. In addition, we didn't conduct the accuracy analysis with additional test area and whole burned area because of restriction of time and computer performance. Therefore, in the future study, the accuracy analysis of whole fire-occurred area must be performed and the amount of loss volume or biomass in forested area must be calculated because forests have national economic value in relation to Kyoto Protocol.

6. CONCLUSIONS

LiDAR system has recently been used to extract surface information as well as canopy of forested area, as it can acquire highly accurate object shape characteristics using geo-registered 3D-points. Therefore, in this study, physical damage could be classified with the assumption that ground returns ratio of LiDAR data in serious damaged area by forest fire might be larger than those in light damaged area. Moreover, NDVI from digital aerial photograph was used to estimate the health of forested area burned by forest fire. Finally, we fused the both raster data and then evaluated the damaged grade into 4 grades - SPD and SBD was 1st grade, SPD and LBD was 2nd grade, LPD and SPD was 3rd grade, and LPD and LBD was 4th grade. As a result, the area of the 1st grade, strong damaged area, was the most broad (65.21%) and 4th grade, weak damaged area, occupied 9.83% of study area. However, in this study, we didn't verify the grading accuracy. Therefore, we must perform the accuracy analysis and quantify the amount of loss forest volume and biomass by forest fire in the future study.

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8. ACKNOWLEDGEMENTS

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