

ASSESSING FOREST FUEL MODELS USING LIDAR REMOTE SENSING

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Abstract

Improving the accuracy of mapping fuel loads is essential for fuel management decisions and explicit fire behavior prediction for real-time support of suppression tactics and logics decisions. The overall aim of this paper is to develop the use of LIDAR remote sensing to accurately and effectively assess fuel models in east Texas. This paper presents methods for using airborne LIDAR (LIght Detection And Ranging) to regain forest parameters critical for fire behavior modeling. The LIDAR data estimates of fuel models were compared with ground truth data collected over 62 plots. The Maximum likelihood and Mahalanobis distance decision rules for supervised image classification were applied to a multispectral QuickBird image and a data fusion stack of LIDAR and multispectral bands. Seven initial classes were considered and classification accuracy was evaluated using confusion matrices and K-hat statistics. The resulting remote sensing methods and mapping products proved to have the potential for driving changes in forest resource management practices related to mitigating fire hazard that threatens public, human lives, and environmental health in Texas and nationwide.

Keywords: *LIDAR software application, Fuel model, Tree height, Tree crown width, Height Bins*

Introduction

Fire is a critical issue in the United States (Falkowski et al., 2005) and fuel distribution is very important for defining fire behavior (Chuvieco and Congalton, 1989). To reduce the fire risk, land managers need to prioritize areas for fire moderating and risky fuels reduction (Falkowski et al., 2005). There is a need to use complex fire behavior models to support environmental assessments to improve ecosystem health (Andrews and Queen, 1999).

In recent years, remote sensing has been increasingly used in estimating fuel properties such as size, compactness, and arrangement (Morsdorf et al., 2004). The use of airborne laser scanning (LIDAR) allows scientists to measure the three-dimensional distribution of forest and it also allows for more accurate and efficient estimation of canopy fuel characteristics over large areas of forest (Andersen et al., 2004). Airborne LIDAR systems have been used for estimating critical parameters for fire behavior. LIDAR has potential to compute and distinguish a range of fuel attributes, including understory fuel height and spatial technology (Means, 2000). Airborne scanning laser system is a powerful tool to get a different source of fuel information.

Objectives

The overall aim of this study is to develop the use of LIDAR remote sensing to accurately and effectively assess fuel models in east Texas. The specific objectives of this study are as follows:

- to develop a framework of reliable processing and analysis techniques to facilitate the use of LIDAR data and multi-spectral imagery to map fuel models; and
- to map vegetation characteristics and produce spatially explicit digital fuel maps.

Methods

Study Area

The study area, Huntsville, is located within 95° 24' 57" W- 30° 39' 36" N and 95° 21' 33" W- 30° 44' 12" N in East Texas. Stands in various stages of development pine-hardwood mixed stands, and hardwood stand in the study area. A QuickBird image of the study area is shown in Figure 1.



Figure 1: Map of Texas indicating the location of Huntsville

LIDAR Data

For this study, we employed both LIDAR scanning data and multispectral data, Quickbird imagery. Scanning LIDAR data was provided by M7 Visual Intelligence. In March 2004, LIDAR data were acquired over an area of 25 square miles. M7VI uses semi-automated process for processing GPS and LIDAR data that includes built-in measures for quality control and assurance throughout each step of the process. A total of

47 flight lines were obtained over the study area, with 19 flight lines obtained from East to West and 28 flight lines obtained from North to South. An average of 2.58 points/m² and a max of 39.84 points/m² were found.

Field Data

The ground truth data were collected from May 2004 to July 2004. In order to assess fuel models and forest inventory parameters and determine the accuracy of airborne LIDAR estimates, ground truth data were gathered for this study. The ground truth data were collected on two separate forms for plot and forest cover description, respectively.

All trees were measured and species were identified within the plot boundaries. First, each tree location was mapped using bearing (precision of measurements: 1 degree) and distance from the plot center (precision: 1 cm using the Vertex Forester instrument). Considering the first live branch, tree height was measured for each tree. In addition, Dbh and crown diameter were determined for each individual tree and trees crown were classified based on the Kraft system such as dominant, co-dominant, intermediate (TSF, 2004). A total of 62 plots were measured in the study area, Huntsville.

Fuel loadings can be quickly estimated by taking a photo series including detailed data for each fuel complex shown (Reeves, 1988). Six digital photographs were taken from each plot center, with two photos taken from a general view and four photos taken facing the north, south, east, and west directions of the study area. Figure 2 (a) represents the location of Plot #1 in the study area and figure 2 (b) represents the digital photos that are taken from the plot center facing north, south, east, and west. These photos were then evaluated for their respective fuel models (Reeves, 1988, and Anderson, 1982).

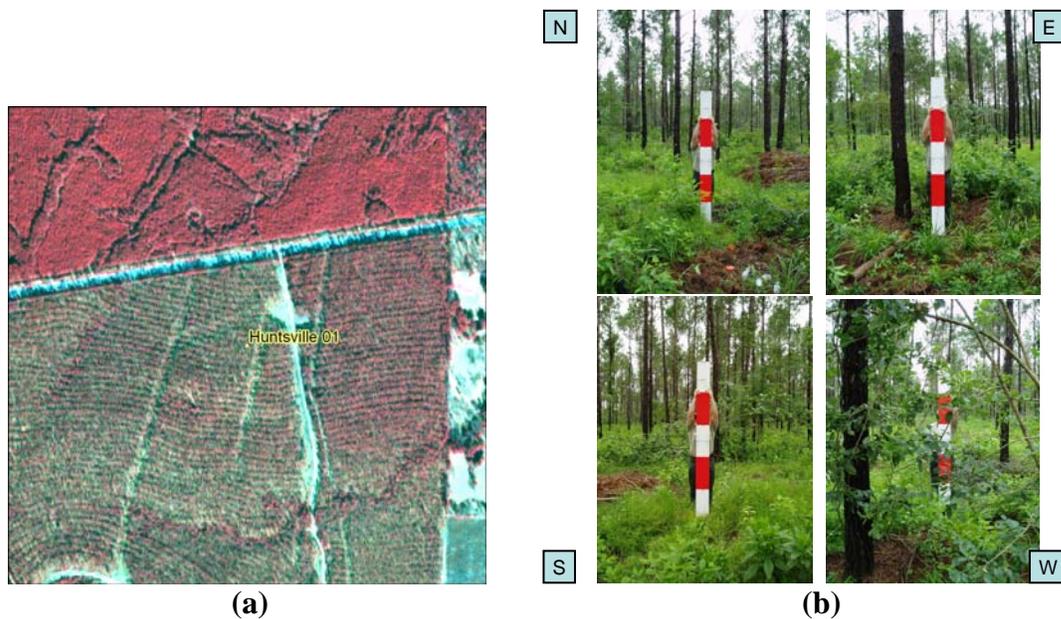


Figure 2: (a) Location of Plot #1 in the study area, (b) digital photos of Plot #1.

Fuel Models

In this study, we want to map vegetation characteristics and produce spatially explicit digital fuel maps. A total of thirteen fuel models are identified for the United States, each varying in amount, size, and arrangement of fuel model (Anderson, 1982). Fuel models are simply tools to help the user reasonably estimate fire behavior (Reeves, 1988) and they represent the fuel condition for a specific site (Rollins et al., 2004). Each plot's fuel model type was determined by Texas Forest Service personnel involved with fire behavior and mitigating efforts. Each of the four photographs available for each plot as well as field inventory data, were analyzed to determine fuel models. A total of seven fuel models are available in our study area: Fuel model 1, Fuel model 2, Fuel model 4, Fuel model 5, Fuel model 7, Fuel model 8, and Fuel model 9. Table 1 represents the description of each fuel model type.

Fuel model	Typical fuel complex
Grass and grass-dominated	
1	Short grass (1 foot)
2	Timber (grass and understory)
3	Tall grass (2.5 feet)
Chaparral and shrub fields	
4	Chaparral (6 feet)
5	Brush (2 feet)
6	Dormant brush, hardwood slash
7	Southern rough
Timber litter	
8	Closed timber litter
9	Hardwood litter
10	Timber (litter and understory)
Slash	
11	Light logging slash
12	Medium logging slash
13	Heavy logging slash

Table 1: Description of fuel models

Processing Approach

In this study, we needed to collect both ground truth data and LIDAR Remote Sensing data. The LIDAR derived fuel map was compared with ground truth data to verify its accuracy. The overall study steps are illustrated in Figure 3.

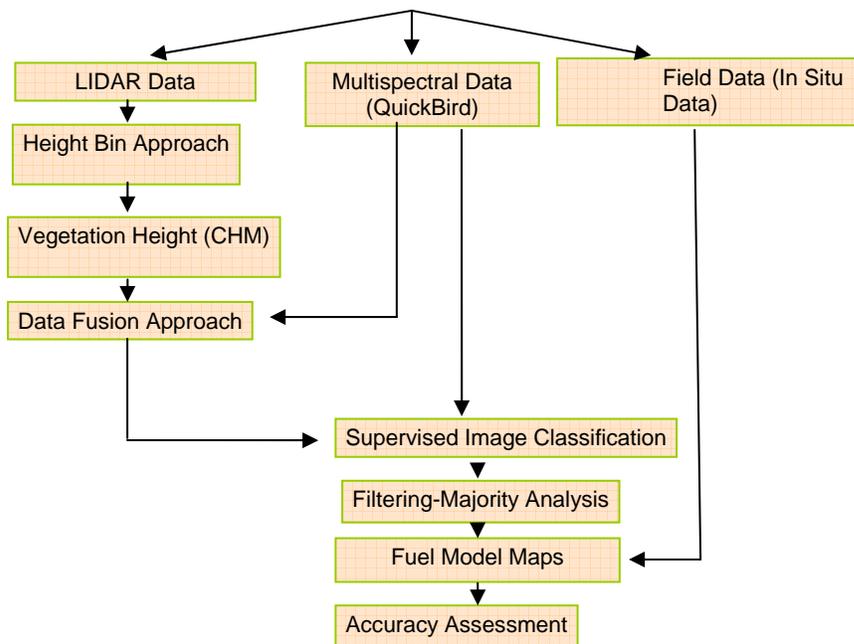


Figure 3: The overall study steps

Height Bins

The height bin approach was used to generate LIDAR multiband data from scanning data. LIDAR Bins were created by counting the occurrence number of LiDAR points within each volume unit and normalizing by the total number of points.

Data Fusion Approach

By using ENVI 4.2, we built a new multiband image. This image includes a total of 10 bands. As is shown in Figure 4, the first four bands are taken from Quickbird image, the fifth band is taken from LIDAR derived canopy cover, sixth, seventh, eighth, and ninth bands are obtained from the first four LIDAR Height Bins (0-0.5, 0.5-1.0, 1.0-1.5, 1.5-2.0 meters), and last band is obtained from canopy height model variance. The fuel mapping results obtained by processing the stack of lidar and multispectral bands were compare to a fuel map derived by classifying the QuickBird image alone.

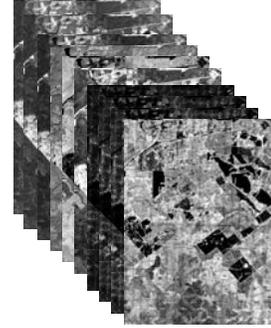
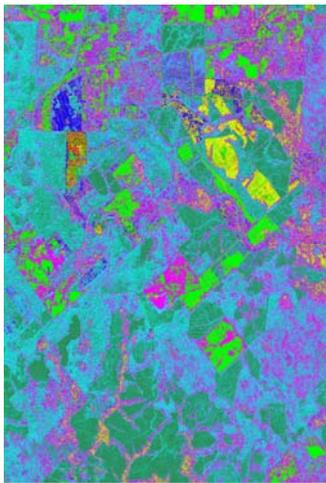


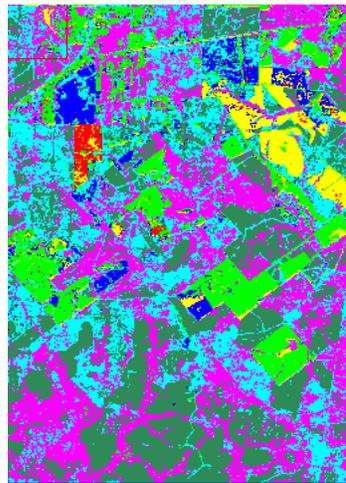
Figure 4: The overall view of the stack of lidar and multispectral bands

Results

The Maximum likelihood and Mahalanobis distance decision rules for supervised image classification were applied to a multispectral QuickBird image and a data fusion stack of LIDAR and multispectral bands. Seven initial classes were considered and classification accuracy was evaluated using confusion matrixes and K-hat statistics. Maximum Likelihood yielded the best results of all the supervised image classification decision rules for Multispectral QuickBird image with 76.52% overall accuracy and 0.68 kappa coefficient. Mahalanobis Distance yielded the best results of all the supervised image classification decision rules for data fusion stack of LIDAR and multispectral imagery with 87.17% overall accuracy and 0.83 kappa coefficient. Figure 5 represents the result of image classification.



(a)



(b)

Red	F-M # 1	Grass
Green	F-M # 2	Grass
Blue	F-M # 4	Brush
Yellow	F-M # 5	Brush
Cyan	F-M # 7	Brush
Magenta	F-M # 8	Timber litter
Sea Green	F-M # 9	Timber litter

(c)

Figure 5: (a) The classification result of multispectral QuickBird image, (b) the classification result of data fusion stack of LIDAR and multispectral imagery, and (c) legend for both image classifications.

Conclusion

The method has a great potential for becoming a standard approach for mapping fuels with LIDAR and multispectral imagery. Compared to the multispectral Quickbird image classification, the data fusion stack of LIDAR and multispectral imagery increased the overall accuracy by 10.65%. The data fusion approach combining LIDAR and multispectral imagery improves the overall accuracy of image classification and can improve estimate of fire fuel models. Our result will be significant in forest policy and forest resource management.

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