SENSITIVITY ANALYSIS FOR FIRE BEHAVIOR MODELING WITH LIDAR-DERIVED SURFACE FUEL MAPS

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ABSTRACT

Research scientists and forest resource managers have been trying to develop models for wildfire behavior for a long time. The overall aim of this project is to determine fire behavior models using FARSITE and investigate differences in modeling outputs using fuel model maps, which differ in accuracy, in east Texas. This software requires as input spatial data themes such as elevation, slope, aspect, surface fuel model, and canopy cover along with separate weather and wind data. A total of thirteen fuel models are identified for the United Stated; however a total of seven fuel models are available in our study area: Fuel Models 1 and 2, the grass group; Fuel Models 4, 5, and 7, the brush models; and Fuel Models 8 and 9, timber litter. These fuel models can serve as input to FARSITE. To perform modeling sensitivity analysis, two different fuel model maps will be used, one obtained by classifying a QuickBird image and the other obtained by classifying a LIDAR and QuickBird fused data set. Our previous investigations showed that LIDAR improves the accuracy of fuel mapping by at least 10. According to our new results, LIDAR derived data also provides more detailed information about characteristics of fire. This study will show the importance of using accurate maps of fuel models derived using new LIDAR remote sensing techniques.
Keywords: LIDAR, Fuel model, FARSITE

INTRODUCTION

Forest fires destroy many houses and natural resources each year. To decrease the loss of life and property due to wildfires, fire managers need to actively evaluate fire risks. Humans are the primary modifiers of fuel sources and ignition source vectors for the propagation of fire (Pyne, 1992). To reduce the threat of the wildfires, Texas fire managers need a tool that helps them assess fire hazards and risks more accurately.

FARSITE (Fire Area Simulator) is a spatially explicit fire growth model developed by Finney (1994). FARSITE produces maps of fire growth and behavior in vector and raster (Stratton, 2004). Many wildland fire managers use this software to simulate characteristics of prescribed wildfires (Finney 1998, Grupe 1998). Spatial data derived from GIS (Geographic Information Systems) and/or remote sensing are required and should be imported into the program. These data layers must be reliable for all lands and ecosystems (Keane et al., 2000). The consistency and accuracy of the input data layers are very important for realistic predictions of fire growth (Keane et al., 1998, Finney 1998). The fuel model map is the key input for the simulation model. Many fire managers do not have the fuel maps needed to run the FARSITE model for their area (Keane, 2000).

Satellite technology can assist in providing data for the FARSITE software (Cheuvieco, 1997). The use of airborne LIDAR (Light Detection and Ranging) allows scientists to measure the three-dimensional distribution of forests, and it allows for more accurate and efficient estimation of canopy fuel characteristics over large areas of forests (Andersen et al., 2005). This technology is useful for obtaining accurate measurements of surface elevations (Bufton et al., 1991). Airborne LIDAR systems can be used for fire detection, location, and mapping (Justice et al., 1993), for burned area assessment, and, important to this study, for fuel mapping (Keane et al., 1998). Multispectral image classification is an important technique in remote sensing and image analysis.

The main objectives of this paper are to determine fire behavior models using FARSITE and investigate differences in modeling outputs using fuel model maps, which differ in accuracy, in east Texas. This study will show the importance of using accurate maps of fuel models derived using new LIDAR remote sensing techniques.

Study area

Fire behavior was modeled for an area in east Texas near Huntsville. Forest stands in study area are in various stages of development, including pine, pine-hardwood mixed stands, and hardwood stands (Mutlu et al., in review). The study area also includes open ground with fuels consisting of grasses and brushes. Figure 1 represents the QuickBird image of the study area.

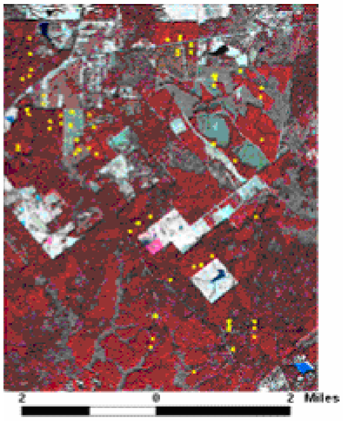
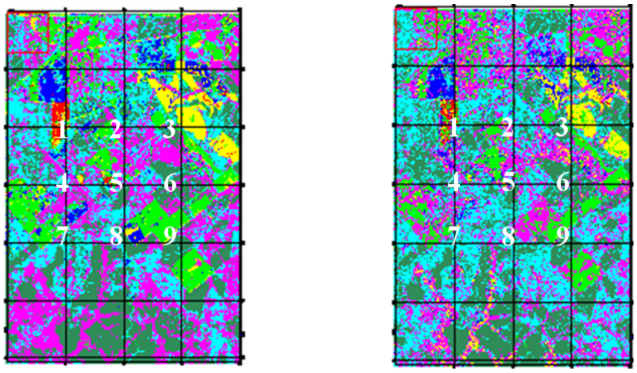


Figure 1. The location of our study area and false color composite of a QuickBird image

METHODS

Two different fuel model maps obtained from Mutlu et al (in review) were used to see the differences in fire growth with fuel model maps of different accuracies (see Figure 2 (a) and (b)).



(a) (b)

Figure 2. (a) The fuel map obtained by classifying a LIDAR and QuickBird fused data set, (b) the fuel model map obtained by classifying a QuickBird image [Gridlines and fire ignition points are included].

Data

FARSITE software requires eight data layers including Digital Elevation Model (DEM), slope, aspect, canopy cover, fuel models map, weather, wind, and fuel moisture for surface fire simulations (Finney, 1995). Two different input data sets were used in this study to generate real-time fire simulation outputs.

Dataset with LIDAR_derived Fuel Map

We developed all the spatial data layers, which are required by FARSITE. The first fuel model map at 2.5 m resolution was derived from LIDAR and is shown in Figure 2(a). Based on Mutlu et al (in review), a LIDAR-QuickBird stack image of ten bands was created by stacking the four bands of the QuickBird image with four

LIDAR height bins, three LIDAR-derived bands, one band from the canopy cover model, and one band from the canopy cover variance. In addition, the height bin approach was used to generate LIDAR multiband data from scanning data (Popescu and Zhao, in review). LIDAR bins were created by counting the occurrence of LIDAR points within each volume unit and normalizing by the total number of points (Popescu and Zhao, in review). A Mahalonobis distance algorithm in ENVI was used to classify the imagery. 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. Canopy cover, the horizontal percentage of area covered by tree crowns at the stand level, was found using methods developed by Rutledge and Popescu (in review). Their study developed the use of airborne laser methods to evaluate various canopy parameters such as canopy cover and Leaf Area Index (LAI). DEM was also obtained from LIDAR. By using ENVI software, slope and aspect were derived from the DEM. Weather and wind data were downloaded from the National Fire and Aviation Management Web Applications (http://www.fs.fed.us/fire/planning/nist/wims_web_userguide.htm). Fuel moisture was derived from field data.

Dataset with QuickBird-derived Fuel Map

The second map, shown in Figure 2(b), was derived from QuickBird data at 2.5 m resolution. Based on the report from Mutlu et al. (in review), a maximum likelihood image classification was used to classify the multispectral image. This fuel model map also includes seven fuel models.

The DEM was downloaded from the National Fire and Aviation Management Web Applications (http://www.fs.fed.us/fire/planning/nist/wims_web_userguide.htm) at 30 meter resolutions, and then converted to 2.5 meter resolution. The slope and aspect data were derived from the DEM in ENVI. Weather and wind data were also downloaded from the National Fire and Aviation Management Web Applications (http://www.fs.fed.us/fire/planning/nist/wims_web_userguide.htm).. Canopy cover and fuel moister were developed based on field data.

FIRE SIMULATION

Both fuel model maps were divided into 24 grids, four columns and six rows. Each grid space is 558 pixels. We chose nine center-points from nine grids on each map. These grids are located in the middle of the study areas (see Figure 2(a) and (b)). FARSITE was run eighteen times, nine times on the dataset with the LIDAR-derived fuel model map and nine times on the dataset with the QuickBird-derived fuel map. Figure 3 shows a screenshot from the FARSITE simulation. The duration of each simulation was 72 hours beginning at 8:00 AM and ending at 8:00 AM three days later. The most extreme weather and wind data, which occurred on January 14, were used for all runs of FARSITE.

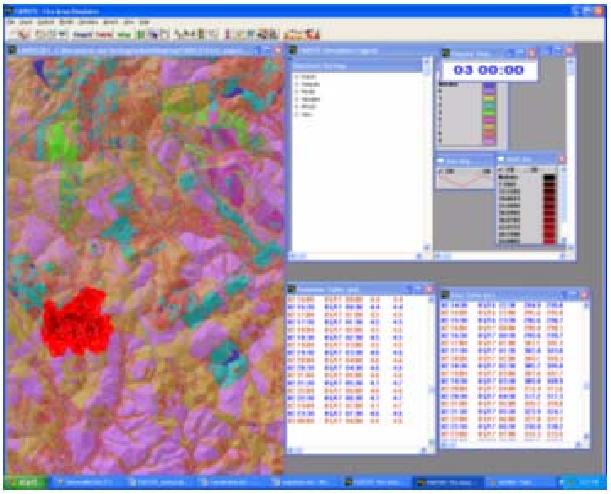
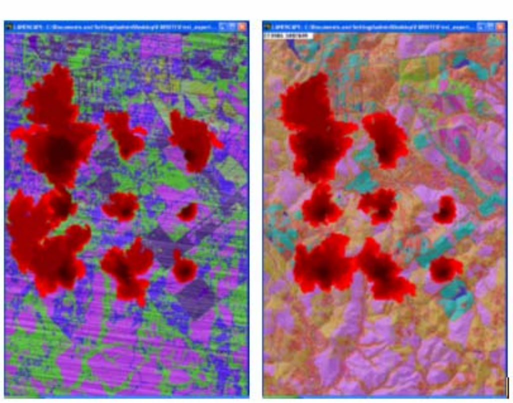


Figure 3. Screenshot from the fire simulation

RESULTS

Figure 4(a) and (b) represent the fire growth outputs for the LIDAR-derived fuel model map and the QuickBird-derived fuel model map. Different accuracy maps provided different results, which were expected.



(a) (b)

Figure 4. (a) The results of fire simulations for the LIDAR-QuickBird fuel map, (b) the results of fire simulations for the QuickBird fuel model map

The comparisons of the burned area results per half an hour are illustrated in Figure 5. Figure 6 demonstrates the comparison of the fire perimeters between the two maps per half an hour for 72 hours.

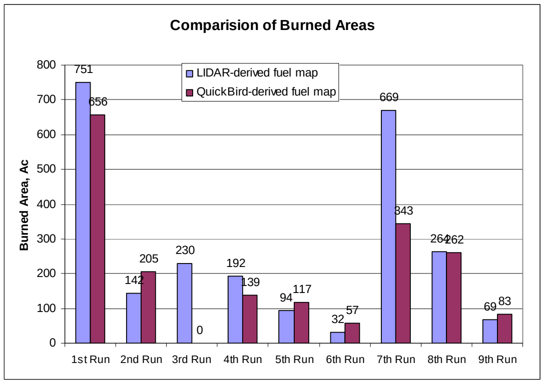


Figure 5. Comparison of burned areas for both fuel model maps

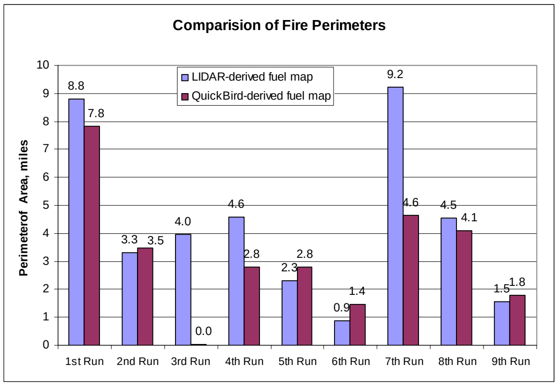


Figure 6. Comparison of fire perimeter results for both fuel model maps

Based upon the fire simulation results, fuel model map derived from LIDAR shows larger fire growth areas than the other fuel model map derived from QuickBird imagery. The estimated total fire growth areas from LIDAR-derived fuel model map and QuickBird derived fuel model map were approximately 2243 ac and 1862 ac, respectively. Apparently, there is a significant difference between the two outputs.

DISCUSSION AND CONCLUSION

In this study, LIDAR data processing by the height bin approach is used to generate accurate estimates of surface fuels parameters and created a fuel model map. Results from this study indicate the influence of a more accurate fuel map on modeling fire behavior and assessing fire risk. According to results, LIDAR derived data provides more detailed information about characteristics of fire. LIDAR derived products were able to assess fuel models with high accuracy and it provided different fire perimeters and fire growth area. 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 the public, human lives, and environmental health in Texas and nationwide.

REFERENCES

Andersen, E.H., McGaughey, J,R., and Reutebuch E.S.,(2005). Estimating forest canopy fuel parameters using LIDAR data. *Remote sensing of Environment 94(4), 441-449.*

Bufton, J.L., Garvin, B., Cavanaugh, J.F., Ramos-Izquierdo, L., Clem, T.D., and Karabill W.B., (1991). Airborne LIDAR for profiling of surface topography. Optical Engineering 30, 72-78.

Cheuvieco E., (1997). A review of remote sensing methods for the study of large wildland fires. Megafires project ENV-CT96-0256. Spain. Pp.192

Finney, M. A. (1994). Modeling the spread and behavior of prescribed natural fires. In Proceedings of the twelfth conference on fire and forest meteorology, edited by J. D. Cohen, J. M. Saveland, and D. D. Wade, 138–43. Bethesda, MD: Society of American Foresters.

Finney, Mark A. (1995). FARSITE Fire Area Simulator Version 1.0 User guide and technical documentation. Systems for Environmental Management Report. Systems for Environmental Management, Missoula, MT. 76 pages.

FINNEY, M.A. (1998). FARSITE: Fire Area Simulator Model development and evaluation. Research Paper RMRS-RP-4. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. 47 p.

Griffin, A.M.R., Popescu, C.S., and Zhao, K. (in review). Using LIDAR and Normalized Difference Vegetation Index to Remotely Determine LAI and Percent Canopy Cover.

Grupe, M. A. (1998). Assessing the applicability of the Terrestrial Ecosystem Survey for FARSITE. Master's Thesis, University of New Mexico, Albuquerque, New Mexico, 95 pages.

Justice, C.O., Malingreau J.P, and Setzer A.W., (1993). Satellite remote sensing of fires: Potentials and limitations in 'Fire in the environment'. Pp. 77-88

Keane, R.E.; Garner, Janice L.; Schmidt, Kirsten M.; Long, Donald G.; Menakis, James P.; Finney, Mark A. (1998). Development of the Input Data Layers for the FARSITE Fire Growth Model for the Selway-Bitterroot Wilderness Complex, USA. USDA Forest Service General Technical Report RMRS-GTR-3. 121 pages.

Keane, Robert E.; Mincemoyer, Scott A.; Schmidt, Kirsten M.; Long, Donald G.; Garner, Janice L. (2000). Mapping vegetation and fuels for fire management on the Gila National Forest Complex, New Mexico, [CD-ROM]. Gen. Tech. Rep. RMRS-GTR-46-CD. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 126 p.

Mutlu, M., Popescu, C.S., Zhao, K., (in review). Using LIDAR-Derived Fuel Maps With FARSITE for Fire Behavior Modeling.

Popescu, C.S., and Zhao, K. (in review). LIDAR tomography of forest vegetation: an application for estimating crown base height for deciduous and pine trees.

Pyne, S.J. (1992). Fire in America, a cultural history of wildland and rural fire. Princeton University Press, 654 pp.

Stratton, D.R., (2004). Assessing the Effectiveness of Landscape Fuel Treatments on Fire Growth and Behavior. Journal of Forestry, October/November 2004. P.32-40