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An Equivalent Fuel Model for Wildland Urban Interface – Application to Risk Management

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Abstract

Wildfires are imposing increasingly greater risk to people and insured properties. The frequency and intensity of destructive wildfires has increased significantly in past decades. Most wildfire damage to properties occurs in the wildland-urban interface (WUI), where properties are either exposed to wildfire directly and burn or are ignited by firebrands. Many wildfire models are focused on modelling the spread of fires in wildland; however, the studies of the spread of wildfires into urban areas is limited. This paper presents a new model for fuel load in urban area using an equivalent fuel load as wildland fuel to simulate wildfire spread when they approach wildland and urban interface/intermix. The model is to estimate the heat release rate from a typical single house and determine the combination of different fuel sizes. Then, according to the density of structures based on satellite imagery the fuel from LANDFIRE fuel is updated with the model urban fuel. A similar method of equivalent fuel load for agriculture area is developed and the LANDFIRE fuel is updated with the agriculture fuel. Using the updated landscape fuel and terrain, Rothermel-based simulation of wildfire is performed in FARSITE. This simulation is helpful in determining the risk of wildfires for properties and communities.

1. Introduction

In recent decades the frequency and significance of wildfires have increased significantly in many parts of the world including the United States (Manzello *et al.* (2018)). Recent fire seasons in the western United States are some of the most damaging and costly on record. Data from California's fire department shows that in 2021 alone, there have been 8,835 wildfires in California which have burned 2,568,948 acres and damaged 3,629 structures. A United Nations report warns that the risk of highly devastating fires may increase by more than 50 percent by the end of the current century, Sullivan (2022). A better understanding of the spatial distribution of wildfire risk will help to mitigate the catastrophic loss of life and properties. This can help by ignition prevention, fuel and vegetation management, enhancing preparedness, and suppression response in high-risk areas as well as reducing human development and increasing home resistance to ignition in fire-prone areas, Calkin *et al.* (2014). This will also help property- and casualty-related industries, such as (re-)insurance industries, to mitigate their financial losses, by designing policies such that the risk of wildfire is considered more accurately (Hazra and Gallagher (2022)).

To estimate the threat of wildfires a stochastic simulation of probabilistic fire scenario is needed (Finney *et al* (2011)[a,b]). This simulation process requires the prediction of occurrence of probabilistic wildfires and simulation of fire growth based on the physical properties of the fuel and terrain and the associated simulated weather. Many models have been developed by researchers including FARSITE and Prometheus, which are simulating the growth of wildland fires (Finney (2004) and Tymstra (2010)). These models simulate the spread of wildfires based on Rothermel (1972)'s Fire Spread in wildland area. A model for the probabilistic simulation of fires in wildland has been developed and a probabilistic risk component of wildland fires has been calculated for the continental United States (Finney *et al* 2011[a,b]). The required wildland fuel models in United States can be acquired from the LANDFIRE website. Landfire data provides a model environment in the form of eight bands raster that includes fuel properties as well as terrain specifications for wildland. But the model environment is limited to wildland and many other applications including urban areas and agriculture lands are considered non-burnable. This work presents a model based on the energy release properties of burning houses and assigns an equivalent fuel model for urban and WUI area as well as agricultural lands. The LANDFIRE fuel is updated with urban and agriculture fuel models for the urban area. The new model can be uploaded to FARSITE or other wildfire simulator that uses LANDFIRE data which enables wildfire simulator to simulate the spread of the wildfires in WUI.

2. Model description

2.1. The heat release of a single house

A model fuel load for houses is designed such that it can produce the same amount of thermal energy as reported in earlier works of Trelles and Pagni (1997) and Rehm *et al.* (2001). The estimated energy release process can be divided in three stages, first the fire grows exponentially and burns at maximum heat release rate for about an hour, and then burning dies down slowly within two steps. At the peak of burning of the involved house, the vegetation around the structure burns and releases thermal energy simultaneously (Trelles and Pagni (1997)). Summation of the heat release rate yields a total energy release for combustion of an involved house, which includes heat release from the structure and its contents. The energy release from burning of the contents is obtained from experimental studies by Blais *et al.* (2020) of burning the contents of a typical U.S. living room. Assuming fuel load of the typical house is distributed uniformly throughout the entire house and considering the footprint of the house, the total fuel load of the content of a typical house is calculated. The model fuel is designed based on the equivalent amount of thermal energy release from structure and content.

2.2. Estimating the fuel load for WUI

The potential fuel loading of urban areas also depends on the number of the houses in each raster cell of LANDFIRE data. The ratio of vegetation fuel load to structure fuel load decreases once we move from the wildland to urban area as the areal density of structures increases (Rehm *et al.* (2001)). To account for the change in fuel type due to the structure density, the structure density in the simulation area is calculated from the US Building Footprint datasets developed by Microsoft (2022). Considering the density of the buildings, the LANDFIRE fuel in urban areas is updated from non-burnable to the new urban fuel.

2.3. Equivalent fuel for agricultural land

Similar to WUI and urban areas, LANDFIRE considers agricultural lands as non-burnable areas. An estimate of the fuel load for agriculture fields is provided by South Carolina's Forestry Commission, which we used for updating LANDFIRE fuel model

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