Landscape Estimates of Total Heat Release and Fuel Consumption from Prescribed Fires: Analysis and Calibration of Sequential Infrared Images from Aircraft

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BACKGROUND AND APPROACH

Prescribed fire is used as a tool in land management systems designed to sustain oak regeneration in eastern mixed-oak forests. One of the most important fire parameters is fuel consumption, which can be estimated from fire radiative energy (**FRE, kJ m^{-2}**) and experimental data. FRE is estimated from the time integration of fire radiative power (**FRP, kW m^{-2}**). Sequential airborne infrared imagery can be used to estimate FRP. Pixels identified as emitting at their peak FRP are then used to estimate FRE. FRE is then extrapolated across the landscape based on a relationship between FRE and cooling rate. Ultimately, given fire behavior, smoke production and ecological effects can be characterized at a landscape scale will be characterized.

Figure 1: *Typical mixed-oak forest prescribed burns are surface fires.*

AIRBORNE FIRE MONITORING

Airborne fire monitoring has become a useful remote sensing method for examining fire behavior at a very high spatial resolution. This project investigates a prescribed fire in southeastern Ohio through remote sensing measurements of emitted radiance. Time-sequence airborne imaging consisted of multiple over-flights with a repeat interval of 3-6 minutes performed by an aircraft equipped with a long-wave infrared (LWIR) camera. Sequential images were analyzed to estimate fire radiative energy and fuel consumption.

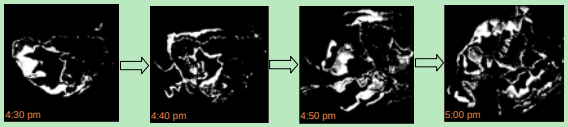


Figure 2: *Time-sequence imaging of the Arch Rock fire as taken on April 17, 2004*

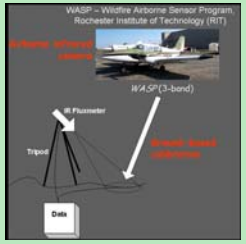


Figure 3: *Ground calibration approach.*

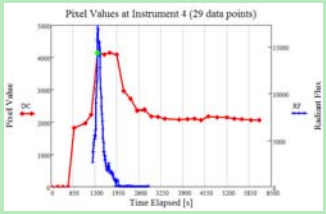


Figure 4: *Comparison between ground-based and aerial LWIR at one pixel*

STUDY AREA

IMAGE ANALYSIS METHODS

Step 1: Image Enhancement

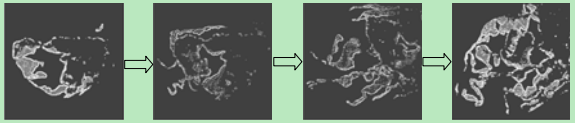


Figure 5: *Gradient magnitude images: rapid radiance changes (contrast)*

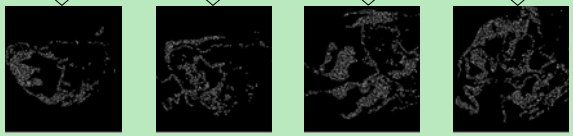


Figure 6: *High gradient magnitude pixels: digital number 255 (in white)*

Step 2: Bi-Spectral Edge Detection

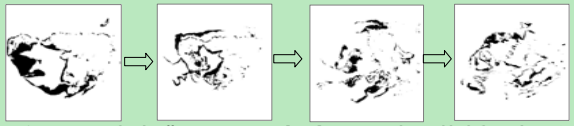


Figure 7: *Normalized Difference Burn Ratio [-1, 1]; negative values in black (burned areas)*

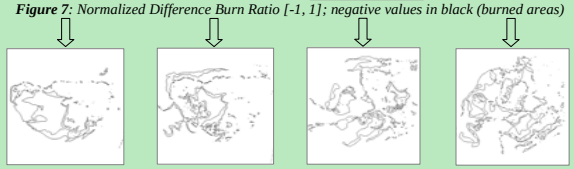


Figure 8: *Edge detection on NDBR; pixels DN = 255 define the fire perimeters (in black).*

Step 3: Fire-Line Pixel Extraction

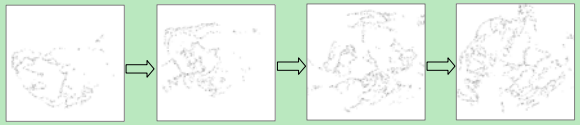


Figure 9: *A Boolean And logical operator was applied to Fig. 5 and 7. Pixels having the same value 255 in both images were coded 1 and all other possible combinations 0.*

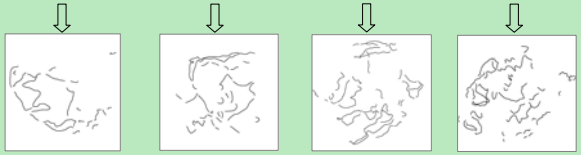


Figure 10: *Linear active fire fronts were edited through the selected active fire pixels. Linear features were then smoothed using a cubic B-spline approximation.*

IMAGE ANALYSIS METHODS, cont.

Step 4: Extracting Peak FRP Pixels

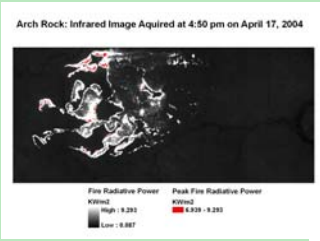
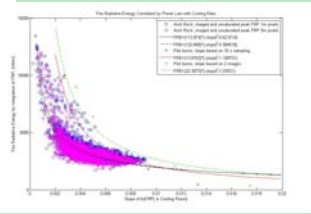


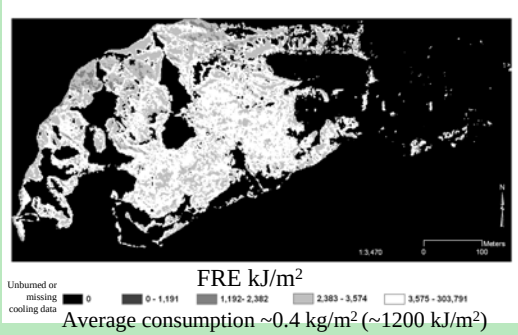
Figure 11: *Because fireline pixels are not peak FRP in the LWIR, a search algorithm, constrained to search within 8 m of the fireline, was used to identify pixels most likely to be at their peak heat release. FRP bin size determined clumping pattern.*

Figure 12: *A power-law relationship between FRE and the cooling rate for peak FRP pixels forms the basis for mapping FRE across the burn unit. Pixel size (1 to 3 m) has no effect, though sampling rate (10 s to ~5 min) has a moderate effect.*



LANDSCAPE FRE

Figure 14: *Map of FRE over the Arch Rock burn unit. The last airborne image occurred when active flaming was still ongoing, thus the image is incomplete on western side.*



Average consumption ~0.4 kg/m² (~1200 kJ/m²)

FUEL CONSUMPTION FROM FRE

Figure 13: *Experimental plot burn.*

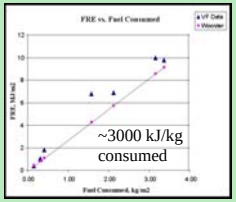


Figure 14: *Correlation between FRE and fuel consumption.*