Predicting Fire Behaviour in the Southern Ontario Tallgrass Prairie

Susan Kidnie
Oct 5, 2010

Wildland Fire Canada Conference
The Tallgrass Prairie Ecosystem

- The tallgrass prairie was once a widespread ecosystem found throughout the central US and southern Canada.
  - Home to 100’s of species of grasses, forbs, animals, birds and insects (including endangered species).
- Its existence is the result of a delicate environmental balance – fire, drought and herbivory.

http://www.museum.state.il.us/exhibits/midewin/grasslandmap.html
Tallgrass Prairie Species

Warm-season grasses

Cool season grasses and forbs

www.kswildflowers.org
Fire and the Tallgrass Prairie

- Fire is essential component in:
  - Maintaining diversity
  - Preventing invasion of woody/invasive species

- How does fire impact tallgrass community structure?
  1. Alters conditions at soil surface
  2. Excludes non-TGP and woody species
  3. Alters nitrogen availability
Fire and the Tallgrass Prairie

- Removing fire removes these benefits

- Prescribed burning is used in the restoration of tallgrass prairie sites
  - One of the most economical habitat management tools available but also carries responsibilities on the part of the practitioners

- Low Complexity Burn Program in Ontario
Objectives

Byram’s Fireline Intensity Equation:

\[ I = H \times W \times R \]

Where:
- \( I \) = Fireline intensity (kW/m)
- \( H \) = Heat of combustion of fuel consumed (kJ/kg)
- \( W \) = Load of the Fuel Consumed (kg)
- \( R \) = Rate of spread (m/s)
Objectives

Byram’s Fireline Intensity Equation:

\[ I = H \times W \times R \]

\( H = \text{Heat of Combustion} \)

1. Do differences in heats of combustion of different tallgrass prairie species contribute to variability observed in fire intensity?
Objectives

Byram’s Fireline Intensity Equation:

\[ I = H \times W \times R \]

\( W = \text{Fuel Load} \)

2. Develop a rapid fuel load assessment technique to assist prescribed burn managers in estimating fuel load.
Objectives

Byram’s Fireline Intensity Equation:

\[ I = H \times W \times R \]

\[ R = \text{Rate of Spread} \]

3. Assess the accuracy of different fire behaviour prediction models in predicting rate of spread in the southern Ontario tallgrass prairie.
1. Heat of Combustion

- Do different tallgrass species release significantly different amounts of energy (per unit mass) (and hence lead to different fireline intensities)?

- Generally in fire behaviour modelling, a constant value is used and thought to be a good assumption
  - Canadian FBP System uses 18,000 kJ/kg
  - American BehavePlus uses 18,622 kJ/kg

- Compare: warm season grasses, cool season grass and forbs
1. Heat of Combustion

- **Methods**
  - Collected grass samples from field (in the fall)
  - Dried and ground samples in lab
  - Used a PAR 1341 Oxygen Bomb Calorimeter to determine heat of combustion
1. Heat of Combustion

## Results

<table>
<thead>
<tr>
<th>Species</th>
<th>Mean (kJ/kg)</th>
<th>Std Dev</th>
<th>Minimum (kJ/kg)</th>
<th>Maximum (kJ/kg)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Bluestem</td>
<td>17,779</td>
<td>488</td>
<td>17,124</td>
<td>18,686</td>
<td>10</td>
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<tr>
<td>Little Bluestem</td>
<td>17,787</td>
<td>339</td>
<td>17,326</td>
<td>18,226</td>
<td>5</td>
</tr>
<tr>
<td>Indian Grass</td>
<td>17,351</td>
<td>446</td>
<td>16,788</td>
<td>17,919</td>
<td>9</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>17,601</td>
<td>67</td>
<td>17,553</td>
<td>17,649</td>
<td>2</td>
</tr>
<tr>
<td>Forbs</td>
<td>18,244</td>
<td>936</td>
<td>17,266</td>
<td>19,312</td>
<td>4</td>
</tr>
<tr>
<td>Kentucky Bluegrass</td>
<td>17,162</td>
<td>1307</td>
<td>16,238</td>
<td>18,087</td>
<td>2</td>
</tr>
<tr>
<td>Brome Grass</td>
<td>15,419</td>
<td>25</td>
<td>15,402</td>
<td>15,437</td>
<td>2</td>
</tr>
</tbody>
</table>
1. Heat of Combustion

- Statistical Analysis
  - Individual hypothesis testing between each species to determine statistical significance existed between means of species
1. Heat of Combustion

- Results cont.
  - Difference in means between brome grass and all other grass except Kentucky bluegrass (another cool season grass)
  - Average difference in means of 13% between brome grass and other grasses and forbs

1. Heat of Combustion

- Discussion
  - Relatively small absolute difference in means of brome grass and other species (average of 13%)
  - Compared to variability of rate of spread and fuel load - very small difference, probably not affecting fire intensity significantly
2. Fuel Load

- Fuel load is critical in determining fire intensity
  - Greater the fuel load, the more intense the fire
  - Important factor to consider when developing a prescribed burn plan for a site
- There is a wide range of fuel loads in tallgrass prairie systems
  - No real guides or tools available to objectively estimate these load
2. Fuel Load

- Fuel load collection from fall 2007 and fall 2008
  - Over 400 samples
- Sampling area ranged from Windsor to Barrie to Peterborough area
2. Fuel Load

- Goal of rapid fuel load assessment is to develop a regression relationship between a known amount of standing vegetation and a predictive variable
  - Plant height
  - Vegetation density
  - Cover
  - Visual obstruction

- Necessary to calibrate models to specific fuel types
- Testing 3 techniques- falling plate meter, Robel pole and grass height
2. Falling Plate Meter

Rayburn and Lozier, 2003
2. Falling Plate Meter
2. Robel Pole/Visual Obstruction

Robel pole being used to estimate fuel load
2. Fuel Load

- Analysis
  - Linear regression models
    - Individual species and site averages
  - Box-Cox Test (Box and Cox 1964) to determine if transformations were necessary
## 2. Results

### Falling Plate Meter Linear Regression Models

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>RMSE</th>
<th>Adjusted $r^2$</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Observations</td>
<td>0.17</td>
<td>0.37</td>
<td>309</td>
</tr>
<tr>
<td>Site averages</td>
<td>0.21</td>
<td>0.56</td>
<td>28</td>
</tr>
<tr>
<td>Big bluestem and Indian grass</td>
<td>0.16</td>
<td>0.27</td>
<td>178</td>
</tr>
<tr>
<td>Little bluestem and switch grass</td>
<td>0.15</td>
<td>0.75</td>
<td>34</td>
</tr>
<tr>
<td>Mixed grasses</td>
<td>0.17</td>
<td>0.37</td>
<td>95</td>
</tr>
</tbody>
</table>

### Robel Pole Linear Regression Models

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<thead>
<tr>
<th>Fuel Type</th>
<th>RMSE</th>
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<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Observations</td>
<td>0.28</td>
<td>0.38</td>
<td>179</td>
</tr>
<tr>
<td>Site averages (all species)</td>
<td>0.2</td>
<td>0.61</td>
<td>17</td>
</tr>
<tr>
<td>Big bluestem</td>
<td>0.28</td>
<td>0.16</td>
<td>49</td>
</tr>
<tr>
<td>Little bluestem</td>
<td>0.25</td>
<td>0.76</td>
<td>13</td>
</tr>
<tr>
<td>Indian grass, Switch grass and Mixed grasses</td>
<td>0.29</td>
<td>0.3</td>
<td>111</td>
</tr>
</tbody>
</table>

### Grass Height Linear Regression Models

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>RMSE</th>
<th>Adjusted $r^2$</th>
<th>n</th>
</tr>
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<tbody>
<tr>
<td>All Observations</td>
<td>0.19</td>
<td>0.21</td>
<td>300</td>
</tr>
<tr>
<td>Site averages</td>
<td>0.15</td>
<td>0.37</td>
<td>27</td>
</tr>
<tr>
<td>Big bluestem, little bluestem and mixed grass (sandy soils)</td>
<td>0.16</td>
<td>0.48</td>
<td>150</td>
</tr>
<tr>
<td>Big bluestem, little bluestem and mixed grass (clay soils)</td>
<td>0.19</td>
<td>0.054</td>
<td>78</td>
</tr>
<tr>
<td>Indian Grass</td>
<td>0.1</td>
<td>0.58</td>
<td>64</td>
</tr>
</tbody>
</table>
2. Results

- Robel Pole and Falling plate meter
  - Site average model

- Site average model

![Falling Plate Meter](image1)

Average Plate Height vs. average fuel load of each site

![Robel Pole](image2)

Average Pole Height vs. average fuel load of each site
2. Results

- Default FBP grass fuel load: 0.3 kg/m$^2$
- Average fuel load from this study: 0.6 kg/m$^2$

- Litter layer linear regression model
3. Rate of Spread

- FBP has 17 fuel types
  - 2 grass fuel types: standing and matted grass
  - Experimental data from Australian grass fires
    - How well does this model predict fire behaviour in tallgrass prairie?
3. Fire Behaviour

- Spring 2008 field season – 6 burns
- Spring 2009 field season – 5 burns
3. Rate of Spread

- Measure rate of spread with rate of spread timers

- Measure:
  - Fire characteristics
  - Weather variables during fire
  - Fuel moisture at time of fire
  - Fuel load
3. Fire Behaviour

- **Fire Behaviour Models**
  - Canadian FBP System (Forestry Canada Fire Danger Group, 1992)
  - American BehavePlus (Rothermel (1972) fire spread model)
  - Australian grass fire spread model (Cheney and Gould, 1997)

- **Fuel Moisture**
  - Actual fuel moisture
  - Fine Fuel Moisture Code (FFMC) – FBP System
  - Wotton’s grass fuel moisture model (Wotton, 2009)
## 3. Rate of Spread

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<thead>
<tr>
<th>Model</th>
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<th>r²</th>
<th>Adjusted r²</th>
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<tbody>
<tr>
<td>FBP - log</td>
<td>Actual</td>
<td>0.003</td>
<td>-0.088</td>
<td>9</td>
</tr>
<tr>
<td>FBP – log</td>
<td>FFMC</td>
<td>0.0048</td>
<td>-0.045</td>
<td>15</td>
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<tr>
<td>FBP – log</td>
<td>GFM</td>
<td>0.11</td>
<td>0.03</td>
<td>15</td>
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<td>Australian - log</td>
<td>Actual</td>
<td>0.54</td>
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3. Rate of Spread

- FBP – very poor relationship between observed and predicted rates of spread
- Australian grass fire spread model and BehavePlus preformed similarly well
  - Recommendation is Australian grass fire spread model
- Need to develop a tallgrass prairie specific fuel moisture model
Applications

- Created **Field Guide for Estimating Fire Behaviour in Ontario’s Tallgrass Prairie**
  - Includes Robel pole info and photo series
  - New Australian fire spread model
- Similar feel and flow to the Red Book, but different models and no indicies
- Guides are available
  - In depth presentation on how to use the guide at Tallgrass Workshop on Friday
  - Also available October and November for individual consultations
Summary

- Differences in heat of combustion not likely contributing to differences in fire behaviour
- Fuel load in TGP is greater than default value being used
  - Robel pole and falling plate meter models to estimate fuel load
- FBP has weak relationship between observed and predicted ROS, recommend Australian grass fire spread model
  - Need for more accurate grass fuel moisture model
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Ontario Ministry of Natural Resources-Aviation and Forest Fire Management
Ontario Ministry of Natural Resources-Ontario Stewardship Opportunity Fund
Ontario Ministry of Natural Resources-Species at Risk Stewardship Fund

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