Methodology to Estimate Burned Biomass using Satellite Images

(Qid. 10350)

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OBJECTIVES

1. To describe the forest fire FRP probability distribution, on several areas of China, as a power law.
2. To obtain the forest fire FRE from the FRP distribution power law.
3. To get the biomass burned on the analyzed areas by means the FRE.
4. To define a relationship between the FRE released and the CO/CO₂ forest fire emissions.
5. To analyze the post-fire environment in terms of the emitted FRE.
**Project Team members**

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1. Introduce
2. Study Area and Data
3. Progress
4. Future Work Plan
Spatially and temporally explicit mapping of the amount of burned biomass by forest fire is needed to estimate atmospheric emissions of greenhouse gases and aerosols.

The active forest fire and burned forest area can be gotten from satellite images.

- **Burned Biomass Estimation Methods**
  - **Burned Area Method**
    \[
    \text{Burned Biomass} = \text{burned area} \times \text{fuel load} \times \text{combustion completeness}
    \]
  - **FRP Method**
    \[
    P(\text{FRP}) = c \cdot \text{FRP}^{-m}
    \]
    (For example: Wooster et al., 2005; Freeborn et al., 2008; S. S. Kumar, 2011)
2. Study Area and Data

Study Area

- **Study Area**
  - 48° ~51°N
  - 127° ~131° E
  - 20° ~24°N
  - 101° ~103° E

![Map showing national forest resources](image)

Key regions
## 2. Study Area and Data

### Satellite Data Collection

Data with forest Fire

<table>
<thead>
<tr>
<th>Production</th>
<th>Years</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATS_TOA_1P</td>
<td>2009</td>
<td>17</td>
</tr>
<tr>
<td>HJ-1B IRS</td>
<td>2009~</td>
<td>20</td>
</tr>
<tr>
<td>FY 3A/B/C VIRR</td>
<td>2009~</td>
<td>420</td>
</tr>
<tr>
<td>GF-1</td>
<td>2014~</td>
<td>180</td>
</tr>
<tr>
<td>GF-2</td>
<td>2014~</td>
<td>54</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>691</td>
</tr>
</tbody>
</table>
2. Study Area and Data

- **Ground Information Collection**
  - **Forest Fire Information**
    The fire information includes fire location, on fire time, fire duration, etc.
  - **Background Information**
    Vegetation map, Forest map, Administrative Boundary, etc.
3. Progress

3.1 Burned Area Estimation Method

3.2 FRP Estimation Method

-Fire Radiative Power (FRP)
3. Progress

3.1 Burned Area Estimation Method

\[ BB = B \times F \times C \]

*BB: Burned Biomass  
B: Burned area  
F: Fuel load  
C: Combustion completeness

Satellite can be used to get the burned area

Fuel loading was derived using a handful of field measurements

Field based parameterizations based on fuel types and fuel moisture
3.1 Burned Area Estimation Method

\[ BB_i = B_i \times F_i \times C_i \]

\[ BB = \sum_{i=1}^{n} BB_i \]

\( i \) is the sub-compartment
3. Progress

- **Field Work**

Burned area, Anning, Yunnan province
3. Progress

Field Work

Burned area, Anning, Yunnan province
3. Progress

Field Work

Unburned area, Anning, Yunnan province
3. Progress

- Burned Area Mapping

Anning, Yunnan province, HJ-1A CCD, Apr. 14, 2013
3. Progress

**Burned Area Mapping**

GF-1 WFV, Sep. 29, 2013
Anning, Yunnan province

GF-1 PMS, Feb. 14, 2014
3. Progress

- Burned Area Mapping

Burned Area by using MODIS, HJ-1A CCD, Anning, Yunnan Province
3. Progress

● Burned Area Mapping

Burned Area by using GF-1, Anning, Yunnan Province
3. Progress

• Burned Fuel Mapping

![Burned Fuel Types](image1.png)

**HJ-1A CCD**

![Burned Fuel Types](image2.png)

**MODIS**
3. Progress

- Burned Fuel Load Mapping

**Burned Fuel Load**

- HJ-1A CCD
- MODIS
3. Progress

- Results

\[ BB = B \times F \times C \]
3. Progress

● Results

\[ \text{BB} = B \times F \times C \]
3. Progress

- Results

![Graph showing the comparison of MODIS and HJ-1A CCD for various categories like Yunnan Pine, Dipan Pine, Fir, Economic Forest, Shrub, Grass, Others, and Total in terms of Kg weight.](chart.png)
3. Progress

• Results
## Results

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>MODIS (kg)</th>
<th>HJ-1A CCD(kg)</th>
<th>Difference(kg)</th>
<th>Relative Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yunnan Pine</td>
<td>521232.00</td>
<td>0.00</td>
<td>521232.00</td>
<td>0.74</td>
</tr>
<tr>
<td>Dipan Pine</td>
<td>124390861.91</td>
<td>65452134.16</td>
<td>58938727.75</td>
<td>84.15</td>
</tr>
<tr>
<td>Fir</td>
<td>359018.20</td>
<td>235800.60</td>
<td>123217.60</td>
<td>0.18</td>
</tr>
<tr>
<td>Economic Forest</td>
<td>1139186.13</td>
<td>393782.88</td>
<td>745403.25</td>
<td>1.06</td>
</tr>
<tr>
<td>Shrub</td>
<td>19697544.90</td>
<td>11093782.62</td>
<td>8603762.28</td>
<td>12.28</td>
</tr>
<tr>
<td>Grass</td>
<td>1806510.00</td>
<td>914094.20</td>
<td>892415.80</td>
<td>1.27</td>
</tr>
<tr>
<td>Others</td>
<td>1144346.90</td>
<td>932544.40</td>
<td>211802.50</td>
<td>0.30</td>
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<tr>
<td>Total</td>
<td>149058700.04</td>
<td>79022138.86</td>
<td>70036561.18</td>
<td>100.00</td>
</tr>
</tbody>
</table>
### 3. Progress

#### Results

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>GF-1 PMS (kg)</th>
<th>GF-1 WFV (kg)</th>
<th>Difference (kg)</th>
<th>R (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yunnan Pine</td>
<td>0.00</td>
<td>11008.00</td>
<td>11008.00</td>
<td>-0.15</td>
</tr>
<tr>
<td>Dipan Pine</td>
<td>94608843.17</td>
<td>90541690.42</td>
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<tr>
<td>Economic Forest</td>
<td>553096.81</td>
<td>2655.35</td>
<td>-550441.46</td>
<td>7.75</td>
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<tr>
<td>Shrub</td>
<td>18939224.23</td>
<td>15843165.94</td>
<td>-3096058.29</td>
<td>43.58</td>
</tr>
<tr>
<td>Grass</td>
<td>1742097.00</td>
<td>1664911.52</td>
<td>-77185.48</td>
<td>1.09</td>
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<tr>
<td>Others</td>
<td>2513504.42</td>
<td>3189824.14</td>
<td>676319.72</td>
<td>-9.52</td>
</tr>
<tr>
<td>Total</td>
<td>118356765.63</td>
<td>111253255.37</td>
<td>-7103510.26</td>
<td>100.00</td>
</tr>
</tbody>
</table>
## Results

<table>
<thead>
<tr>
<th>Sub-compartment Number</th>
<th>GF-1 PMS (kg)</th>
<th>GF-1 WFV (kg)</th>
<th>Difference (kg)</th>
<th>R (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4156</td>
<td>251157.76</td>
<td>256055.03</td>
<td>4897.27</td>
<td>-0.07</td>
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<tr>
<td>4300</td>
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<td>4041.92</td>
<td>-0.06</td>
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<td>4307</td>
<td>107000.44</td>
<td>140208.23</td>
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<td>4313</td>
<td>305305.61</td>
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<td>123164.61</td>
<td>120621.01</td>
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<td>4353</td>
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<td>4356</td>
<td>144927.56</td>
<td>323715.94</td>
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<tr>
<td>4360</td>
<td>859584.17</td>
<td>915335.96</td>
<td>55751.80</td>
<td>-0.78</td>
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<td>4377</td>
<td>49496.14</td>
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<td>4382</td>
<td>45586.46</td>
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<tr>
<td>4386</td>
<td>414624.98</td>
<td>829293.56</td>
<td>414668.58</td>
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<td>4406</td>
<td>317127.01</td>
<td>520308.77</td>
<td>203181.75</td>
<td>-2.86</td>
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<tr>
<td>4420</td>
<td>3798.33</td>
<td>0.00</td>
<td>-3798.33</td>
<td>0.05</td>
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<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
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<td>118356765.63</td>
<td>111253255.37</td>
<td>-7103510.26</td>
<td>100.00</td>
</tr>
</tbody>
</table>
3. Progress

3.1 Burned Area Estimation Method

3.2 FRP Estimation Method

-Fire Radiative Power (FRP)
3. Progress

➢ Field Work

Thermal Camera
3. Progress

Field Work

Temperature Change of Flaming

- Fire
- Background
- Trend
3. Progress

Field Work

\[ \text{FRP} = \varepsilon \times \delta \times A \times T^4 \]

\[ \varepsilon : 0.95 \]
\[ \delta : 1.38 \times 10^{-23} \]
3. Progress

Field Work

Thermal Video Camera
3. Progress

Field Work

Thermal Video Camera

\[
\begin{align*}
  y &= 258.8e^{-0.008x} \\
  R^2 &= 0.0002 \\
  y &= 167.98x^{0.0588} \\
  R^2 &= 0.0283 \\
  y &= 16.973\ln(x) + 150.5 \\
  R^2 &= 0.0291 \\
  y &= -4E-05x^2 + 0.15x + 179.47 \\
  R^2 &= 0.1699
\end{align*}
\]
3. Progress

- FRP Analyzing (MODIS, Year 2001~2014)
3. Progress

- FRP Analyzing

Needle-leaf Forest, MODIS
3. Progress

- FRP Analyzing

*Fire Radiative Power (FRP)*

Broadleaf Forest, MODIS
3. Progress

> FRP Analyzing
P(FRP) = c \cdot FRP^{-m}

Where: P(FRP) is the probability distribution function of FRP
       c is a constant, m is a scaling parameter

\[
\ln P = \ln c - m \cdot \ln FRP
\]

\[
FRE_{power\ law} = d\langle FRP \rangle = d(1 - m) \left( \frac{1}{FRP_{\text{max}}^{-m+1} - FRP_{\text{min}}^{-m+1}} \right) \left( \frac{FRP_{\text{max}}^{-m+2} - FRP_{\text{min}}^{-m+2}}{2 - m} \right)
\]

Biomass Burned = 0.368 \times 10^3 FRE  \quad (\text{Wooster et al., 2005})
3. Progress

Results

$log(p) = -2.5484 \ln(FRP) + 33.807$
$R^2 = 0.9875$

$log(p) = -2.4758 \ln(FRP) + 18.766$
$R^2 = 0.9589$

Needle-leaf Forest

Broadleaf Forest
3. Progress

- Results

Mixed Forest

$$\ln(p) = -3.221 \ln(\text{FRP}) + 36.217$$
$$R^2 = 0.9418$$

Shrub

$$\ln(p) = -2.6329 \ln(\text{FRP}) + 21.298$$
$$R^2 = 0.9769$$
## Results

### Results of burned biomass estimated

<table>
<thead>
<tr>
<th>Class</th>
<th>$m$</th>
<th>Lnc</th>
<th>$FRE$ (J)</th>
<th>Burned biomass (T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Needle-leaf Forest</td>
<td>2.5484</td>
<td>33.807</td>
<td>$1.8 \times 10^8$</td>
<td>$7.1 \times 10^7$</td>
</tr>
<tr>
<td>Broadleaf Forest</td>
<td>2.4758</td>
<td>18.766</td>
<td>$2.0 \times 10^8$</td>
<td>$7.3 \times 10^7$</td>
</tr>
<tr>
<td>Mixed Forest</td>
<td>3.2210</td>
<td>36.217</td>
<td>$1.7 \times 10^8$</td>
<td>$6.3 \times 10^7$</td>
</tr>
<tr>
<td>Shrub</td>
<td>2.6329</td>
<td>21.298</td>
<td>$1.7 \times 10^8$</td>
<td>$6.1 \times 10^7$</td>
</tr>
</tbody>
</table>
3. Progress

FRP Analyzing

Active fire, MODIS, Anning, Yunnan Province
3. Progress

Anning, Yunnan, MODIS, Mar., 2012, FRP_{min} = 16.10\text{Wm}^{-2}, \text{FRP}_{max} = 205.0\text{Wm}^{-2}, \text{FRP}_{ave} = 122.35\text{Wm}^{-2}

N=24
3. Progress

FRP Analyzing

Xunke, Heilongjiang, MODIS
3. Progress

FRP Analyzing

Active Fire, MODIS, Apr. 28~ May 11, 2009
3. Progress

➢ FRP Analyzing
3. Progress

Xunke, Heilongjiang, MODIS, Apr., 2009, FRP_{min}=7.0\text{Wm}^{-2}, \text{FRP}_{max}=1718.5\text{Wm}^{-2}, \text{FRP}_{ave}=114.68\text{Wm}^{-2}
4. Future Work Plan

➢ To analyse the post-fire recover
Thanks!