Use of Thematic Mapper Satellite Imagery, Hemispherical Canopy Photography, and Digital Stream Lines to Predict Stream Shading

David Nagel – GIS Analyst
Charlie Luce – Research Hydrologist
Bárbara Gutiérrez Teira – Post Doctoral Research Biologist

This research was conducted by scientists and analysts at the U.S. Forest Service, Boise Aquatic Sciences Lab, Boise, ID.
The study area is located in central Idaho, encompassing the Middle and North Forks of the Boise River watershed.
Studies at the Boise Lab often focus on the interactions between biological and physical sciences.
Stream temperature research exemplifies the importance of linking biological and physical sciences.
Stream temperature research is important for developing management plans for thermally sensitive species such as bull trout.
Disturbances such as fire and debris flows are an important part of the physical template that influences biology.
This graphic illustrates the extent of disturbance due to fire and debris flows within our study area.
Objective

Estimate incident solar radiation at the stream surface, at the landscape scale, to help understand observed differences in water temperature.

The study objective.
The study incorporates four important data collection components. We assume that instream temperatures are influenced by shade. Shade (radiation) was mapped using satellite imagery and estimated along the stream channel.
Instream temperatures were collected between July and September in 10 streams, with 10 thermographs in each stream.
### Streams and Mean Temperature

<table>
<thead>
<tr>
<th>Stream</th>
<th>Mean Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver</td>
<td>9.49 °C</td>
</tr>
<tr>
<td>Lost Man</td>
<td>9.65</td>
</tr>
<tr>
<td>Hungarian</td>
<td>10.27</td>
</tr>
<tr>
<td>French</td>
<td>10.82</td>
</tr>
<tr>
<td>Trail</td>
<td>11.32</td>
</tr>
<tr>
<td>Lost</td>
<td>13.69</td>
</tr>
<tr>
<td>SF Sheep</td>
<td>13.71</td>
</tr>
<tr>
<td>Cottonwood</td>
<td>13.71</td>
</tr>
<tr>
<td>Trapper</td>
<td>14.13</td>
</tr>
<tr>
<td>Wren</td>
<td>15.55</td>
</tr>
</tbody>
</table>

This is a list of the study streams and their summer mean temperatures. Tidbit Temperature Loggers were used.
We also collected hemispherical canopy photography throughout the study area. Our objective was find a relationship between radiation predictions derived from canopy photos and stream temperature.
Hemispherical Canopy Photography

- Sites distributed among different vegetation types and stream sizes
- Processed photos using Hemiview software
- Total June radiation, direct and diffuse
- Radiation values range from 118 – 1038 MJ/m²yr
- Collected horizontal photos

Specifics regarding canopy photography.
Horizontal photos were collected at each canopy photo location. Sites 31B and 38A represent the sites with the lowest and highest radiation estimates. Radiation values range from 118-1038 megajoules per square meter per year.
Radiation increased as vegetation cover classes moved from closed canopy conifer to an open structure.
The canopy photos were binned into three broad vegetation cover classes, open, shrub, and conifer and the mean radiation value was computed for each class.
Differences Between Cover Classes

**Anova: Single Factor**

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
<th>Sum</th>
<th>Average</th>
<th>Variance</th>
<th>Standard Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>50</td>
<td>39307.41</td>
<td>786.1482</td>
<td>23423.55</td>
<td>151</td>
</tr>
<tr>
<td>Shrub</td>
<td>28</td>
<td>19261.56</td>
<td>687.9129</td>
<td>25274.24</td>
<td>156</td>
</tr>
<tr>
<td>Conifer</td>
<td>103</td>
<td>49046.61</td>
<td>476.1807</td>
<td>28118.68</td>
<td>166</td>
</tr>
</tbody>
</table>

**ANOVA**

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F</th>
<th>P-value</th>
<th>F crit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>3522722</td>
<td>2</td>
<td>1761361</td>
<td>66.73152</td>
<td>2.38701E-22</td>
<td>3.046722</td>
</tr>
<tr>
<td>Within Groups</td>
<td>4698264</td>
<td>178</td>
<td>26394.74</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8220986</td>
<td>180</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ANOVA analysis showed that the radiation difference among classes was significant.
What We Know So Far

Mean temperature for 10 streams

Mean radiation for three cover classes

- Open
- Shrub
- Conifer

We don’t know where these cover classes are on the landscape

At this point, we now have mean temperature measures for 10 streams and mean radiation values for three cover types.
Landsat 7 TM Satellite Imagery

- Acquired July 10, 2002
- 30 m spatial resolution
- Rectified using 2 m DOQ and terrain data
- Topographic normalization completed

Thematic Mapper satellite imagery was acquired for the purpose of mapping vegetation classes along the stream channel.
The cover types of open, shrub, and conifer were easily identifiable in the satellite imagery.
The satellite imagery was classified using standard image classification techniques.
The vegetation classification product along side the satellite imagery.
The overall accuracy of the satellite derived vegetation classification was about 75%.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Classified</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>26</td>
<td>4</td>
<td>20</td>
<td>50</td>
<td>52%</td>
</tr>
<tr>
<td>Shrub</td>
<td>3</td>
<td>16</td>
<td>9</td>
<td>28</td>
<td>57%</td>
</tr>
<tr>
<td>Conifer</td>
<td>2</td>
<td>7</td>
<td>94</td>
<td>103</td>
<td>91%</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
<td>27</td>
<td>123</td>
<td>181</td>
<td>75%</td>
</tr>
</tbody>
</table>

The table shows the accuracy of classification for different vegetation types based on reference data.

84% 59% 76% 75%
Stream lines were derived from DEMs using TARDEM software.
TARDEM Streams

- Software developed by David Tarboton – Utah State University
- Streams derived from DEM data
- Output in ArcInfo coverage format
- Coverage contains useful stream characteristics attributes
- TauDEM – ArcGIS plug-in

http://www.engineering.usu.edu/dtarb/

TARDEM information.
What We Know Now

Mean temperature for 10 streams

Mean radiation for three cover classes
  - Open
  - Shrub
  - Conifer

Location of cover classes on the landscape

Location of the streams

Summary of the full dataset includes stream temperature data, radiation estimates, vegetation classification, and stream network.
Raster Extraction

- Use stream lines to extract cover types
- ArcGIS Spatial Analyst
- Select a thread of pixels that touch the stream line
- 1000 m upstream from last logger

Vegetation data was extracted along the stream channel.
Example of the vegetation extraction along Beaver Creek.
The average radiation was computed for each stream with temperature records.

<table>
<thead>
<tr>
<th>Beaver Creek Cover</th>
<th>Radiation</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>786</td>
<td>172.92</td>
</tr>
<tr>
<td>Shrub</td>
<td>687</td>
<td>309.15</td>
</tr>
<tr>
<td>Conifer</td>
<td>476</td>
<td>157.08</td>
</tr>
</tbody>
</table>

639.15 MJ/m²yr
We found a positive relationship between stream temperature and radiation derived from satellite imagery. Each point represents radiation and temperature for each of the 10 streams.

Regression of Radiation and Temperature

Total Radiation vs. Mean Temperature

\[ y = 0.0242x - 4.1435 \]

\[ R^2 = 0.6681 \]
We also looked at radiation values in streams with various types of disturbance.
We found that radiation was strongly associated with disturbance class.
Caveats

- Temperature loggers were within a narrow elevation band, 1000 – 1800 m
- Accuracy assessment points were not randomly distributed
Initial Conclusions for this Dataset

- Radiation can be estimated using canopy photography and associated with vegetation types.
- Vegetation can be mapped using satellite imagery at a scale that is appropriate for estimating stream temperature.
- Stream temperature increases with increasing radiation, mapped from satellite imagery.
- Radiation values can be linked to riparian disturbance classes.
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