Human-Environment Systems & Disturbance in the Okavango Delta

Dr. Kelley A. Crews
Director, GIScience Center
Department of Geography & the Environment
The University of Texas   Austin, Texas USA
Context & Caveats

- Geography as **grounded inter**disciplinary
- Relatively new project underscores multi-scale heterogeneity
- Human-environment interactions
  - LULCC, disturbance ecology
  - Livelihood systems & vulnerability
  - Forecasting HIV/AIDS landscapes
- Comparative framework and benefits of geographically diverse network(s)
“Disturbance”

- Deviation from the norm
- Influence ecosystem structure and function through competition and resource availability
- Influence livelihoods through changing the context of adaptation
- Key [ecological] structuring process at mid-scales... positive influence
Okavango Delta, Botswana

Internationally recognized as Ramsar Wetland of Importance (Botswana became contracting partner in 1997)

Delta plays ecological, hydrological, biological role in region

Wetland extent is 8,000 – 15,000 km²

Seasonal landscape and cloud conditions
Characterization of flooding & fire

- Convenience of existing collaborative datasets
- Ecological time series
  - Permanent signals (trend, cycle, structured residual)
  - Transitory signals (disturbance)
- Relation to livelihood systems, management plans, and climatic cycles
Seasonally Inundated Floodplains

Photo from Aquarap 2000 survey
Okavango Delta, Botswana

(advancing flood front)

Photo by Susan Ringrose
Remotely Sensed Imagery

- Multi-temporal, multi-spectral database
  - Landsat 5 Thematic Mapper (70 scenes, 1989 – 2000) *
  - Landsat 7 Enhanced TM+ (17 scenes, 1999 – 2003) **
  - EO-1 Advanced Land Imager (26 scenes, 2001 – 2003) ***
  - 1.5 years of data geo-rectification and pre-processing to establish database
  - 30 m spatial resolution, ~2 - 3 month temporal resolution

- Ancillary data
  - GIS layers and shapefiles ****
  - MODIS products (daily acquisitions, 1 km spatial, 2001 - today)
  - IKONOS (2 scenes, 2000, 4/1 m spatial) **
  - SRTM Digital Elevation Model

Data Provided by:
  * Technische Universitaet Muenchen
  ** NASA Safari 2000 Mission
  *** NASA EO-1 Scientific Calibration/Validation Mission
  **** HOORC
Field Work

Observed vegetation patterns on landscape

Assessment of trends in data with corresponding vegetation
Extract Flood/Fire

Flood and Fire distribution extracted using unsupervised classification.

1991 June 24 subset of study area. Bands 4, 7, 2 shown.
Seasonality of Regimes

Average Seasonality of Flooding and Fire Regime

- **Flood**
- **Fire**
- **Precipitation**

### Average Spatial Extent (km²)

- **Jan**
- **Feb**
- **Mar**
- **Apr**
- **May**
- **June**
- **July**
- **Aug**
- **Sept**
- **Oct**
- **Nov**
- **Dec**

### Average Precipitation (mm)

- **Jan**
- **Feb**
- **Mar**
- **Apr**
- **May**
- **June**
- **July**
- **Aug**
- **Sept**
- **Oct**
- **Nov**
- **Dec**
Processing Steps

Radiometric/Atmospheric Correction

Compute Enhanced Vegetation Index (EVI)

Cluster EVI time-series

Build 35 Trajectories

Harmonic Regression on trajectories

Wavelets to identify periodicities in residuals

Updated Harmonic regression

Compared both TOA and apparent surface reflectance

EVI is used as a surrogate for vegetation

ISODATA: resulting in 35 temporal clusters

Compute statistics under cluster mask to build 35 trajectories

Harmonic regression on EVI trajectories to examine components of permanent signal

Wavelet decomposition identifies other periodicities in vegetation response

2nd Harmonic regression using identified periodicities to compute overall goodness of fit
14-year Vegetation Trends

**Strong Increase** – Floodplains

**Increase/Neutral** – Riparian, Woodlands & Grasslands in rural areas

**Decrease** – Rural savanna and woodlands

EVI Change from 1989 - 2002

- Strong Increase
- Increase
- No Increase
- Decrease
Trends based on Flooding/Fire

14-year Spatial Association of Flooding and Fire

Browns → Fire Only
Blues → Flood Only
Greens → Both Flooding and Fire

Identified all pixels with similar disturbance history (e.g. burn 1, flood 4)

Stratified pixels by land management (e.g. hunting vs. photography concessions or Moremi vs. communal)

Results: Higher $R^2$ tend to be associated with lower burning, more flooding, and not in the communal areas.
Overall Regression $R^2$

Variability in vegetation response appears to be largely cyclical.

Applying semi-annual, annual, and quasi-decadal cycles:

- Riparian vegetation had best $R^2$ (0.88)
- Seldom flooded areas had $R^2$ (0.63)
Temperature Trends at Maun Airport

Maun Airport
Annual Temperature Trends

$y = 0.0373x + 30.054$
$R^2 = 0.2583$

$y = 0.0462x + 14.529$
$R^2 = 0.4294$

~0.4 °C/10 years
Climatic Signals

80-year precipitation record from Maun airport
Precipitation data from Botswana Meteorological Services

IMPORTANT: Correlation is not causation
Lessons learned

- Jargon, dialogue, and buy-in (capacity building)
- Importance of local collaborators, regional heterogeneity
- Portability of approach - to whom do we build crosswalks?
- Time investment in building / cementing networks and “language training”
- Public administration and development studies communities
thank you

kacm @ uts.cc.utexas.edu
digital.landscapes @ gmail.com

Financial Support: NASA, NSF, UT
Logistical Support: SGI, HOORC

Data Provided by:
Technische Universitaet Muenchen
NASA Safari 2000 Mission
NASA EO-1 Scientific Calibration/Validation Mission
Harry Oppenheimer Okavango Research Centre
## Temporal Spacing of Imagery

**Maun Airport Monthly Precipitation Totals (mm) Source Botswana Meteorological Services**

Yellow boxes indicate coincident Landsat image

<table>
<thead>
<tr>
<th>Year</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>88/89</td>
<td>12.9</td>
<td>14.5</td>
<td>46.0</td>
<td>215.5</td>
<td>180.0</td>
<td>44.3</td>
<td>96.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>7.6</td>
</tr>
<tr>
<td>89/90</td>
<td>17.4</td>
<td>5.5</td>
<td>41.5</td>
<td>87.1</td>
<td>110.0</td>
<td>33.3</td>
<td>17.3</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>90/91</td>
<td>28.5</td>
<td>13.3</td>
<td>78.4</td>
<td>177.6</td>
<td>134.0</td>
<td>123.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>5.8</td>
</tr>
<tr>
<td>91/92</td>
<td>6.7</td>
<td>40.7</td>
<td>55.1</td>
<td>50.1</td>
<td>7.4</td>
<td>87.9</td>
<td>5.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>92/93</td>
<td>14.3</td>
<td>23.9</td>
<td>155.0</td>
<td>66.5</td>
<td>122.0</td>
<td>15.4</td>
<td>47.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.7</td>
<td>0.0</td>
<td>0.0</td>
<td>8.2</td>
</tr>
<tr>
<td>93/94</td>
<td>0.0</td>
<td>44.0</td>
<td>15.2</td>
<td>275.0</td>
<td>50.0</td>
<td>6.2</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>94/95</td>
<td>16.6</td>
<td>54.1</td>
<td>10.4</td>
<td>27.0</td>
<td>14.4</td>
<td>0.0</td>
<td>2.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>22.0</td>
<td>11.0</td>
<td>146.5</td>
</tr>
<tr>
<td>95/96</td>
<td>3.5</td>
<td>105.0</td>
<td>46.1</td>
<td>189.3</td>
<td>281.0</td>
<td>9.0</td>
<td>0.4</td>
<td>2.9</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>5.5</td>
</tr>
<tr>
<td>96/97</td>
<td>26.6</td>
<td>24.8</td>
<td>67.8</td>
<td>153.8</td>
<td>19.2</td>
<td>64.8</td>
<td>1.8</td>
<td>5.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>13.0</td>
<td>0.0</td>
</tr>
<tr>
<td>97/98</td>
<td>1.7</td>
<td>50.5</td>
<td>109.0</td>
<td>150.2</td>
<td>18.6</td>
<td>28.4</td>
<td>32.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>98/99</td>
<td>7.9</td>
<td>14.2</td>
<td>63.5</td>
<td>110.0</td>
<td>56.5</td>
<td>41.2</td>
<td>3.8</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>99/00</td>
<td>5.7</td>
<td>43.7</td>
<td>45.0</td>
<td>255.0</td>
<td>183.5</td>
<td>31.2</td>
<td>21.7</td>
<td>2.3</td>
<td>2.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>00/01</td>
<td>0.0</td>
<td>126.2</td>
<td>29.3</td>
<td>34.0</td>
<td>103.8</td>
<td>47.7</td>
<td>87.8</td>
<td>3.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>01/02</td>
<td>22.3</td>
<td>126.4</td>
<td>41.4</td>
<td>58.6</td>
<td>36.0</td>
<td>15.3</td>
<td>6.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>12.8</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>02/03</td>
<td>31.2</td>
<td>69.1</td>
<td>54.9</td>
<td>30.5</td>
<td>51.1</td>
<td>5.5</td>
<td>30.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>