Determining trends in impervious cover for the Mobile Bay, AL region for 1974-2008, based on a Landsat time series

J.P. Spruce, J.C. Smoot, J.T. Ellis, and R. Swann

This presentation will discuss the development and use of Landsat-based impervious cover products in conjunction with land use land cover change products to assess multi-decadal urbanization across the Mobile Bay region at regional and watershed scales. This nationally important coastal region has undergone a variety of ephemeral and permanent land use land cover change since the mid-1970s, including gradual but consequential increases in urban surface cover. This urban sprawl corresponds with increased regional percent impervious cover. The region’s coastal zone managers are concerned about the increasing percent impervious cover, since it can negatively influence water quality and is an important consideration for coastal conservation and restoration work. In response, we processed multi-temporal Landsat data to compute maps of percent impervious cover for multiple dates from 1974 through 2008, roughly at 5-year intervals. Each year of product was classified using one single date of leaf-on and leaf-off Landsat data in conjunction with Cubist software. We are assessing Landsat impervious cover product accuracy through comparisons to available reference data, including available NLCD impervious cover products from the USGS, raw Landsat data, plus higher spatial resolution aerial and satellite data. In particular, we are quantitatively comparing the 2008 Landsat impervious cover products to those from QuickBird 2.4-meter multispectral data. Initial visual comparisons with the QuickBird impervious cover product suggest that the 2008 Landsat product tends to underestimate impervious cover for high density urban areas and to overestimate impervious cover in established residential subdivisions mixed with forested cover. Landsat TM and ETM data appears to produce more accurate impervious cover products compared to those using lower resolution Landsat MSS data. Although imperfect, these Landsat impervious cover products have helped the Mobile Bay National Estuary Program visualize basic urbanization trends for multiple HUC-12 watersheds of concern to them and their constituents.

Keywords: impervious cover trend analysis Landsat
Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data

Presented to the 2012 ASPRS Conference by:
Joseph Spruce, Computer Sciences Corporation (CSC)
James Smoot, CSC
Jean Ellis, University of South Carolina (Project PI)
Roberta Swann, Mobile Bay National Estuary Program
Introduction

• The Mobile Bay region is invaluable to the nation in terms of economic benefits and ecological services
• Coastal communities surrounding this estuary have grown during the past 50 years. This urbanization has led to impaired water quality for many waterways draining into the bay.
• The amount of impervious cover in a given watershed can negatively influence water quality and aquatic biota
• Impervious cover is an important factor in managing and/or promoting coastal regional water quality and fisheries
• In response, our project team began in 2010 to develop and assess a time series of impervious cover maps from 1974-2008
• This presentation discusses the results of this study as part of a bigger project to assess land-use land-cover (LULC) change in the region
Previous Work: LULC Maps Derived from Landsat Data

1974 LULC from Landsat MSS Data

2008 LULC from Landsat TM Data

For more information, see Ellis et al. (2011) in Journal of Coastal Conservation
Research Goal and Objectives

• Goal - Assess trends in impervious cover between the years of 1974-2008, based on impervious cover products derived from Landsat Multispectral Scanner System (MSS), Thematic Mapper (TM), and Enhanced Thematic Mapper (ETM+) data
  – Objective 1 - Assess potential of computing impervious cover products from Landsat TM/ETM+ data to supplement existing National Land Cover Database (NLCD) products
  – Objective 2 - Assess potential of computing impervious cover products using Landsat MSS data
Impervious Cover Mapping Method
--- For Each Targeted Year ---

- **Landsat Fall or Summer Date**
  - Multi-Channel Data Stack of Both Dates
    - Reflectance bands
    - NDVI
    - Principal Components 1, 2, 3
    - Tasseled Cap brightness, greenness, wetness

- **Landsat Winter or Spring Date**

**ISODATA Classification of Pure Impervious Cover**

**Initial % Impervious Cover Classification**
- NLCD Mapping Tool
- Percent Calculation Module
- Done for geographic subset
- % impervious cover for input pixels, providing training data

**Creation of Sampling Data**
- NLCD Mapping Tool – Sampling Tool
- Subsamples input to compute training samples for Cubist

**Developing Decision Tree Model**
- Cubist software
- Iterative runs, outputting correlation and error statistics for each run
- Process results in selection of best decision tree model, based on quality metrics and sub-parameter settings

**Final % Impervious Cover Map**
- Cubist software
- Application of decision rule classifier
- Employs best decision tree model
### Landsat Data Used to Compute % Impervious Cover (IC) Time Series

<table>
<thead>
<tr>
<th>Year</th>
<th>Landsat Data Type</th>
<th>Path</th>
<th>Row</th>
<th>Acquisition Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>Landsat MSS</td>
<td>22</td>
<td>39</td>
<td>11/12/74 and 04/10/74</td>
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<tr>
<td>1979</td>
<td>Landsat MSS</td>
<td>22</td>
<td>39</td>
<td>10/26/79 and 05/26/79</td>
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<tr>
<td>1984</td>
<td>Landsat MSS</td>
<td>22</td>
<td>39</td>
<td>09/06/84 and 06/02/85</td>
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<tr>
<td>1987</td>
<td>Landsat TM</td>
<td>21</td>
<td>39</td>
<td>01/02/87 and 07/29/87</td>
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<tr>
<td>1991</td>
<td>Landsat TM</td>
<td>21</td>
<td>39</td>
<td>02/14/91 and 09/26/91</td>
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<tr>
<td>1996</td>
<td>Landsat TM</td>
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<td>39</td>
<td>01/27/96 and 05/02/96</td>
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<tr>
<td>2001</td>
<td>Landsat ETM+/TM</td>
<td>21</td>
<td>39</td>
<td>03/05/01 and 06/17/01</td>
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<tr>
<td>2005</td>
<td>Landsat TM</td>
<td>21</td>
<td>39</td>
<td>04/09/05 and 09/16/05</td>
</tr>
<tr>
<td>2008</td>
<td>Landsat TM</td>
<td>21</td>
<td>39</td>
<td>03/01/08 and 08/07/08</td>
</tr>
</tbody>
</table>
2001 Project IC Map versus Landsat True Color RGB

Project % IC for 2001

Landsat ETM+ Acquired 3-5-2001

Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data.
Project IC Map for 2001 versus NLCD IC Map for 2001

Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data
Project IC Map for 2005 versus NLCD IC Map for 2006

Project % IC for 2005

NLCD % IC for 2006

Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data.
Project IC Map for 2008
versus QuickBird IC Map for 2008

Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data
Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data
Example 2001 Mean % IC Map According to HUC-12 Sub-Watersheds

Landsat ETM+ Data with HUC-12s Acquired March 5, 2001

Project % IC for 2001 Overlaid onto 2001 Landsat RGB

Project 2001 Mean % IC for HUC-12 Sub-Watersheds

<table>
<thead>
<tr>
<th>Range in % IC</th>
<th>Range in Color on % IC Maps</th>
<th>Watershed Health Class Description, Based on Schuler (1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>&gt;= 1%</td>
<td>10%</td>
<td>Blue</td>
</tr>
<tr>
<td>&gt; 10%</td>
<td>25%</td>
<td>Yellow</td>
</tr>
<tr>
<td>&gt; 25%</td>
<td>100%</td>
<td>Red</td>
</tr>
</tbody>
</table>

Class 1 - stressed aquatic biota
Class 2 - impacted aquatic bio-diversity
Class 3 - most degraded, lowest bio-diversity

National Aeronautics and Space Administration

Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data
NLCD versus Project 2001 Mean % IC Map for HUC-12 Sub-Watersheds

Landsat ETM+ Data with HUC-12s
Acquired March 5, 2001

NLCD 2001 Mean % IC for HUC-12 Sub-Watersheds

Project 2001 Mean % IC for HUC-12 Sub-Watersheds

Range in % IC | Range in Color on % IC Maps | Watershed Health Class Description, Based on Schuler (1994)
--- | --- | ---
Low | High | Low | Mid | High
>= 1% | 10% | Class 1 - stressed aquatic biota
> 10% | 25% | Class 2 - impacted aquatic bio-diversity
> 25% | 100% | Class 3 - most degraded, lowest bio-diversity
MSS-Based % IC Map for 1974 Compared to MSS and Corona Data

Landsat MSS Data
Acquired November 12, 1974

1974 % IC Map from Landsat MSS

Corona Data
Acquired December 12, 1968

Efforts to map impervious cover for the Mobile Bay, Alabama region for 1974-2008, based on Landsat data.
Comments on Results

- Landsat TM IC products produced in this project demonstrated good overall visual agreement when compared with NLCD impervious cover maps
  - Especially for the 2001 HUC-12 mean % IC products
- The 2008 QuickBird IC product from this project showed less IC in residential areas, compared to the 2008 TM IC map or the 2006 NLCD IC
- IC products from MSS data appeared to under classify low % IC areas, compared to available reference data
- IC mapping results may be improved by the use of better training data if/when available
- MSS-based IC products for low IC residential areas may be improved with other image processing methods
Final Remarks

• Impervious cover maps were produced from Landsat data for 9 dates between 1974-2008
• The products provide a means to view change in impervious cover at regional and sub-watershed scales
• The products are now being used for aiding coastal zone conservation work being conducted by the Mobile Bay National Estuary Program (NEP)
• In particular, the products are being used to aid HUC-12 watershed health studies - see on-line video example at: http://www.mobilebaynep.com/land_use/
• For more information on this presentation, email joseph.p.spruce@nasa.gov

Participation in this work by Computer Sciences Corporation, Inc., was supported by NASA at the John C. Stennis Space Center, Mississippi, under contract NNS10AA35C. Work on this project was funded by a NASA ROSES grant (# NNX10AC57G, PI: Ellis).