A Remote Sensing and GIS-based Wetland Analysis In Canaan Valley, West Virginia

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A REMOTE SENSING AND GIS-BASED WETLAND ANALYSIS IN CANAAN VALLEY, WEST VIRGINIA

A thesis submitted to
the Graduate College of
Marshall University

Master of Science in Geography

by

Yisha Shi

Approved by
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James Leonard, Ph.D.

Marshall University
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ABSTRACT

A Remote Sensing and GIS-based Wetlands Analysis
In Canaan Valley, West Virginia

by Yisha Shi

With the increasing influence in climate change and human activity, more and more people have begun to recognize the benefits of wetlands. However, there was a continuous annual net loss in the wetlands area since 1980s. Many programs have been implemented to monitor the status and trend of wetlands recently. In West Virginia, the wetlands area is a small portion of the State’s land, but it plays a key role in the whole ecosystem. This research aimed to detect the land cover and vegetation changes focusing on Canaan Valley area, which represents the greatest wetlands area of West Virginia. Remote sensing datasets and GIS were used to analyze the trend change with the supervised maximum likelihood classification and Post-classification change detection methods. The potential causes of wetland loss were analyzed after the classification.
Chapter I: Introduction

Overview of wetlands in United States

In 1979, Cowardin defined wetlands as “lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.” This definition is widely used to regulate wetland areas today (Cowardin et al., 1979). There are two general types of wetlands in United States: freshwater wetlands (95%) and marine or estuarine (saltwater) wetlands (5%). The three dominant categories of freshwater wetlands are forested wetlands, emergent wetlands and shrub wetlands. In 2004, about 51% of America’s Freshwater wetlands were Forested wetlands, and about 25.5% of Freshwater wetlands were Emergent wetland (U.S. Fish and Wildlife Service 2005).

For a long time, a wetland was considered as a land area surrounded by water with little economic value. People thought it was only the habitat for hydrophytes and insects. Because of this negative view, people neglected the importance of wetlands in the whole ecosystem. A lot of wetlands were occupied by agricultural areas such as human-made ponds and drains for crops. For urban development, many wetlands were replaced by industrial facilities and resident houses. According to the report of U.S. Fish and Wildlife Service (2011), the total wetland area was estimated as 110.1 million acres in the United States by 2009. Less than half of America’s original wetlands remained.

With the increasing influence in climate change and human activity, more and more people have begun to recognize the benefits of wetlands. Much effort has been put into wetland protection (Table 1.1). “Section 404 of the Clean Water Act is the primary vehicle for Federal regulation of some of the activities that occur in wetlands” (Votteler and Muir...
As the result of those protection programs, there was a first estimated annual net gain in wetlands of 32,000 acres from 1998 to 2004 (U.S. Fish and Wildlife Service 2005). However, there still was a slight annual net loss between 2008 and 2009.

Table 1.1: Examples of wetland protection programs and acts

<table>
<thead>
<tr>
<th>Program or Act</th>
<th>Implementing agency</th>
<th>Effect of program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive Order 12630, Constitutional Takings (1988)</td>
<td>AFA</td>
<td>Provides a review process for agencies to protect against unintentional “takings” of private property.</td>
</tr>
<tr>
<td>Federal-Highway Act (1968)</td>
<td>DOT</td>
<td>Highway construction can affect wetlands at every stage. Wetlands are often prime sites for highways.</td>
</tr>
<tr>
<td>Federal Crop Insurance (1980)</td>
<td>USDA</td>
<td>Indirectly encourages farmers to place frequently inundated areas, including wetlands, into production.</td>
</tr>
<tr>
<td>Federal Livestock Grazing</td>
<td>USFS,BLM</td>
<td>Overgrazing promotes the loss of riparian habitat.</td>
</tr>
<tr>
<td>Flood Control Act (1966)</td>
<td>Corps</td>
<td>Authorized various flood-control projects resulting in wetland destruction</td>
</tr>
<tr>
<td>National Flood Insurance Program (1968)</td>
<td>FEMA</td>
<td>Encourages development in flood plains, which contain wetlands, by providing low-cost Federal Insurance.</td>
</tr>
<tr>
<td>Coastal Zone Management Act (1972)</td>
<td>NOAA</td>
<td>Provides Federal funding for wetlands programs in most coastal States, including the preparation of coastal zone management plans.</td>
</tr>
<tr>
<td>Wetlands Loan Act (1961)</td>
<td>FWS</td>
<td>Provides interest-free loans for wetland acquisition and easements.</td>
</tr>
</tbody>
</table>

History of wetlands detection and monitoring

The U.S. Fish and Wildlife Service is the main responsible agency in wetland conservation in United States. The key responsibly is to determine the status and trends of the nation’s wetland habitats. The National Wetlands Inventory (NWI) Program was established by the US Fish and Wildlife Service to produce wetland maps and geospatial wetland data for the United States since the mid-1970s. The Wetlands Status and Trends
monitoring is “a quantitative measure of the areal extent of all wetlands in the conterminous United States” (U.S. Fish and Wildlife Service 2005).

Since the early 1980s, satellite imagery has become commonly used to improve change detection in wetlands (Dahl 2004). The U.S. Fish and Wildlife Service has used remote sensing techniques to determine the vegetation cover of wetlands for the past 25 years. Currently, the status of mapping wetlands has been made available through various media. Much of this work is accomplished using high altitude aerial photography (1:80,000 to 1:40,000 scale). The Fish and Wildlife Service will continue to produce national updates on wetlands status as well as more rigorous information on wetland trends.

Status and trend of West Virginia’s Wetlands

West Virginia’s wetlands are located in the Mid-Atlantic region. All wetland areas belong to freshwater wetlands systems. Canaan Valley and the Meadow River area are two main wetlands in West Virginia, representing about 14% of the state’s wetlands. Despite the fact that West Virginia’s wetland areas are very small, only 102,000 acres representing less than 1 percent of the state’s area (West Virginia Division of Natural Resources 1987); they provide many benefits to the local environment, such as erosion control, flood reduction, surface water quality improvement, plus fish and wildlife habitat. Between 1957 and 1980, nearly 6,000 acres (22%) of emergent wetland were lost. However, both forested and shrub wetlands increased, and freshwater ponds increased by 225 percent due to agriculture and urban development (Tiner 1987).

West Virginia’s wetlands are regulated through the Federal Clean Water Act. Although the state has no specific wetland protection laws, the government made a lot of effort to monitor the changes in West Virginia’s wetlands. In 2011, West Virginia Department of Environmental Protection and West Virginia Division of Natural Resources
created a four-year wetland protection plan to manage and regulate West Virginia’s Wetlands. The West Virginia Wetland Program Plan (WPP) has five core elements: Monitoring and Assessment; Restoration and Protection; Water Quality Elements; Regulation and Outreach; Information, Education and Coordination (West Virginia Wetland Program Plan 2011).

Objectives

The objective of this study is to detect the total wetland changes from 1993 to 2002 in the Canaan Valley area by using Supervised Maximum Likelihood Classification and Post-classification change detection methods. Geographic Information System and Remote Sensing technologies are used to process the data. Then the study aims to examine the potential causes relative to the wetland changes with other reference data.

The following questions need to be answered in this study:

1. Did the wetland change significantly with an increasing or decreasing rate from 1993 to 2002?
2. Where was the greatest wetland change area in Canaan Valley? What was the rate of change?
3. What could have been the major cause of wetland changes in Canaan Valley?
Chapter II: Literature Review

Application of Remote Sensing in wetlands monitoring

Classifying wetlands is the basic step for wetlands inventory. After that, wetland changes can be detected from the classified images. At the global level, it provides readily understood terms, a framework for international legal instruments for wetland conservation, and assists in the dissemination of information (Scott & Jones, 1995). Recently, digital classification of wetland from satellite image data has been widely used because these methods are less time consuming and the source data provide high temporal resolution and high accuracy in georeferencing procedures (Jensen 1996, Coppin et al., 2004). Many datasets have been successfully used in wetland classification, such as aerial photographs, Landsat data, and Système Pour l’Observation de la Terre (SPOT) data, but Landsat-based classification is considered providing the greatest accuracies (Civco 1989, Hewitt 1990, Bolstad and Lillesand, 1992) because of the sensitivity of Landsat bands. The Landsat TM and ETM+ have similar 7 bands (Table 2.1), while ETM+ band 6 has a higher resolution of 60 meters. The Landsat 7 satellite also has newly added panchromatic band 8 with resolution of 15 meters.

Table 2.1: Landsat TM Bands and wavelength range.

<table>
<thead>
<tr>
<th>Band</th>
<th>Region</th>
<th>Wavelength</th>
<th>Resolution(meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blue-green</td>
<td>0.45 - 52 μm</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Green</td>
<td>0.52 - 0.60 μm</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>Red</td>
<td>0.63 - 0.69 μm</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Near IR</td>
<td>0.76 - 0.90 μm</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Mid IR</td>
<td>1.55 - 1.75 μm</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>Thermal IR</td>
<td>10.4 - 12.5 μm</td>
<td>120</td>
</tr>
<tr>
<td>7</td>
<td>Mid IR</td>
<td>2.08 - 2.35 μm</td>
<td>30</td>
</tr>
</tbody>
</table>
TM band 1 can detect water for bathymetric (water depth) mapping along coastal areas and is useful for soil-vegetation differentiation and for distinguishing forest types. TM band 2 can detect green reflectance from healthy vegetation, and band 3 is designed for detecting chlorophyll absorption in vegetation. TM band 4 is ideal for near-infrared reflectance peaks in healthy green vegetation and for detecting water-land interfaces. The two mid-infrared bands on TM are useful for vegetation and soil moisture studies, and discriminating between rock and mineral types. The thermal-infrared band on TM is designed to assist in thermal mapping, and for soil moisture and vegetation studies.

Unsupervised and supervised classification techniques are most common approaches in wetlands analysis (Ozesmi & Bauer, 2002). The main difference between supervised and unsupervised classification methods is that in supervised classification, the users need to create the training sites to identify the pixel that belongs to which class. Then the remaining patterns will be identified as the members of each predefined class during classification. But in unsupervised classification, the pattern is assigned to a hitherto unknown class. One limitation of supervised classification is the misclassification happened in creating training sites will affect the final classified results. For example, with supervised maximum likelihood classification method, Ndzeidze (2008) chose the Region of Interest tool (ROI) to create training sets of pixels. Every selected pixel, both within and outside the training sites, was evaluated and assigned to the class where it had the highest likelihood of being a member.

Decision tree classification is also widely used. Two different classification methods were used by Baker et al. (2006) to map wetlands area in the Gallatin Valley of Southwestern Montana. Classification Tree Analysis (CTA) uses a one-step-look-ahead
procedure to reduce variance. The results were found that Stochastic Gradient Boosting (SGB) classification (86% overall accuracy) provided higher effectiveness than CTA (73.1% overall accuracy). But one limitation of SGB classification was that it classified moist upland sites as wetlands, which would cause an overestimation in wetlands inventory.

To detect the wetland changes, some techniques are based on comparison of classified results from different periods. For example, post-classification comparison has been applied to determine the total area of wetland change and to identify specific locations of such annual changes in Seoul, Korea (Choung and Ulliman 1992). Post-classification classifies images from different dates separately and then compares class values on pixel by pixel basis between dates. High sensitivity to the individual classification accuracies is a major drawback of this classification. Error is multiplicative from parent maps. But post-classification can avoid a need for strict radiometric calibration and favor the classification scheme of the user. Ferguson et al. (1993) used post-classification to produce effective maps of changes in Sea grass habitat and Jensen et al. (1987) did post-classification change detection to monitor wetland change in the Savannah River swamp forest.

Other techniques, such as Change vector analysis (CVA) by Baker et al. (2007) and land cover change mapper (LCM) by Castilla et al. (2009), are based on spectral change between acquisition dates. The CVA method looks at changes in pixel values by considering the pixel locations for the two dates in the multi-dimensional spectral space. It identifies a change magnitude threshold which is used to separate actual land cover changes from subtle changes (Hame et al., 1998). However, like other radiometric change approaches, CVA has a lack of automatic or semiautomatic methods to effectively determine the threshold of change magnitude between change and no-change pixels. LCM works better
with small areas and is very effective also in identifying areas with significant changes. The limitation is the type of change in the area has to be identified by the analyst unless the analyst does a specific change.

**Application of Geographic Information System (GIS) in wetland change detection**

Geographic Information System (GIS) is another widely used technique in wetlands analysis. Modern GIS gives users the ability to conduct visual and quantitative analysis involving multiple kinds of digital spatial data, including remotely sensed imagery. In most studies, Landsat data after classification are combined with GIS data for future wetland analysis. Sader et al. (1995) used both supervised and unsupervised classification methods to map the Landsat data. Then Ancillary topography, geology, and hydrology Geographic Information System (GIS) data sources are used to model forested wetland characteristics. With GIS, different component layers can be overlaid to investigate relationships between individual wetland components. Classified images can be combined with additional shape files, such as permanent water bodies, rivers, soils types and population changes (Mahmud et al., 2011). These data provide extra information to detect the changes of wetlands and potential causes of the changes.

The National Research Council has identified geographic information system methods as a key element in future wetland management programs in 1993. GIS can be used to perform area calculations on the classified images. The index, such as soil hydrologic group, land use/soil type combination, groundwater residence time, and location of septic system can be calculated by GIS to estimate the necessary data input (Poiani 1996). In wetlands detection programs, GIS is used to calculate the total wetland area changes and change rates.
Chapter III: Methodology

Study area

The study area, Canaan Valley wetland area of Tucker County, is an oval, bowl-like upland valley located in northeastern of West Virginia (Figure 3.1). Canaan Valley contains an expansive and unique wetland complex at the headwaters of the Blackwater River. Since 1994, almost 70% of the valley has become the Canaan Valley National Wildlife Refuge, the nation’s 500th National Wildlife Refuge. About 60% of Canaan Valley is protected as part of the Canaan Valley National Wildlife Refuge.

![Figure 3.1: Wetland in Canaan Valley area.](image)

The total area of Canaan Valley National Wildlife Refuge was estimated as 16,628 acres by U.S Fish and Wildlife Service in 1994. The Canaan Valley freshwater wetland was ranked the largest wetland area in West Virginia, representing about 9% of State’s wetlands.
Canaan Valley wetlands include bogs, marshes, and swamp forests. The area hosts more than 580 plant species, 290 vertebrate species, and threatened and endangered species. Many of the plant and animal species in Canaan Valley are atypical for the area and are usually found in more northerly regions.

Data collection

In order to compare the wetland area differences, the Landsat 5 TM images in 1992, 1993, 1999, 2002 and 2005 with 30 meters resolution (Table 3.1) were downloaded from the Earth Science Data Interface (ESDI) website produced by Global Land Cover Facility (GLFC) and U.S. Geological Survey (USGS).

Table 3.1: Landsat images by TM and ETM+ from 1992 to 2005

<table>
<thead>
<tr>
<th>Landsat Sensor</th>
<th>Date Acquired</th>
<th>Path/Row</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM (Band 1-7)</td>
<td>1992-10-02</td>
<td>17/33</td>
</tr>
<tr>
<td>TM (Band 1-7)</td>
<td>1993-7-17</td>
<td>17/33</td>
</tr>
<tr>
<td>TM (Band 1-7)</td>
<td>1999-5-15</td>
<td>17/33</td>
</tr>
<tr>
<td>ETM+ (Band 1-5, 7)</td>
<td>1999-9-12</td>
<td>17/33</td>
</tr>
<tr>
<td>TM (Band 1-7)</td>
<td>2002-5-23</td>
<td>17/33</td>
</tr>
<tr>
<td>ETM+ (Band 1-7)</td>
<td>2005-9-15</td>
<td>17/33</td>
</tr>
</tbody>
</table>

The scene with Worldwide Reference System 2, Path-17/Row-33 was used to acquire the Landsat images which fully cover the Canaan Valley area. In addition to these data sets, rainfall data was collected to assist in selection of the images (Figure 3.2). The vegetation is different from dry season to rainy season. In this study, the rainy season is the best period to detect the wetland because some wetlands are shown as grassland or exposed soil when they dry up in the dry season. Thus, the images used to detect the
wetland changes were selected from May to July with highest precipitation during the year. Other dry season images were used as reference data when classifying the wetland areas. In addition, a topographic map from 1990 with scale 1:6000 and a true color aerial photography images from 2008 with 6 inch resolution were other important reference data during image classification.

![Figure 3.2: Five year average precipitation in Canaan Valley area](source: The Weather Channel)

The image processing task was carried out using Earth Resource Data Analysis System (ERDAS) 2010. Then ArcGIS 10.0 was used to the remaining tasks, such as image overlay, reclassification and data export.

Data processing

With remote sensing, the objects can be distinguished based on the amount of light that the objects reflect across the various wavelengths that satellites measure. But satellites don’t directly measure reflectance; they measure radiance. The pattern of radiance across the satellite bands is often similar to the pattern of reflectance across the same bands, but at-satellite radiance is altered by atmospheric effects because the light reflecting off the ground goes through the atmosphere before reaching the satellite. Another issue is that we often need to directly compare the reflectance of objects measured on the ground with reflectance calculated from satellite data. So the first step was to
convert satellite digital numbers (DNs) to radiance data and then to ground reflectance with ERDAS. The equations I used are listed below:

\[ L_i = \left( \text{gain}_i \times \text{DN}_7 \right) - \text{bias}_i \]

Where \( L \) is the calculated radiance [in Watts / (sq. meter * mm * ster)], \( \text{DN}_7 \) is the Landsat 7 ETM+ DN data (or the equivalent calculated in step 2), and the gain and bias are band-specific numbers.

\[ R_i = \frac{\pi \times L_i \times d^2}{E_{\text{sun},i} \times \sin(\theta_{SE})} \]

Where \( R \) is the reflectance (unitless ratio), \( L \) is the radiance calculated in step 3, \( d \) is the earth-sun distance (in astronomical units), \( E_{\text{sun}} \) is the band-specific radiance emitted by the sun, and \( \theta_{SE} \) is the solar elevation angle.

Then the Landsat data single band images need to be composited as a multi-band image. Due to the lack of band 6 (Thermal infrared) in 1999’s image, only six bands (1-5, 7) were used for analysis. The Nearest Neighbor Resampling method was used when stacking the images. The Nearest Neighbor method is often used to resample categorical or integer data (for example, land use, soil, or forest type), or radiometric values, such as those from remotely sensed images because it does not change any of the values of cells from the input layer (ESRI 2012). After bands stacking, the raw Landsat dataset were composed to three multi-band images with 30 meters spatial resolution. Because all images were chosen from cloud-free days with good contrast, atmospheric correction was not necessary.

The three images were then processed through ERDAS Supervised Maximum Likelihood Classification with band combination (4, 3, 2). The parametric rules and Parallelepiped as non-parametric rule were used to improve the output results ultimately. The band combination (4, 3, 2) is the standard “false color” composite. Band 3 can
discriminate the healthy vegetation. It also can exhibit more contrast than bands 1 and 2 because of the reduced effect of atmospheric attenuation (Jensen 2005). Using Band 4 results in more defined water boundaries than in the 3,2,1 image, yet the two visible bands still reveal some water detail and give information about the wetlands and flooded areas. The whole image was displayed as a strong red hue with band 4 sensing peak chlorophyll reflectance. Human eyes can easily discriminate subtle tone variations in this color. In addition, band 5 (middle infrared) has the ability to discriminate vegetation and soil moisture levels because it provides for much of the separability between wetland types (Jensen et al. 1996). Therefore, the images shown with band combination (4, 5, 3) can be a reference map to help locating the wetland. Generally, the wetter the soil, the darker it appears, because of the infrared absorption capabilities of water.

The Supervised Maximum Likelihood classification used in this study is the most common method in remote sensing image data analysis (Richards 1995). It identifies and locates land cover types that are known a priori through a combination of personal experience, interpretation of aerial photography, map analysis and fieldwork (Jensen 2005). It uses the means and variances of the training data to estimate the probability that a pixel is a member of a class. The pixel is then placed in the class with the highest probability of membership (Ozesmi and Bauer 2002).

According to Lyon (2001), the preparation of a scheme is a prerequisite in the classification process. This scheme is very useful to create a training site using an Area of Interest tool (AOI) in the classification process. Details of the classes and their description are provided in Table 3.2. The AOI was selected to classify the land cover based on observed land cover classes combined with the author’s knowledge of the Canaan Valley area. The
examples of the selection of land use and land cover classes in the training site are shown in
the figure below (Figure 3.3).

Table 3.2: Land use classification scheme

<table>
<thead>
<tr>
<th>Land Use</th>
<th>Code</th>
<th>Description</th>
<th>Appearance Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>WA</td>
<td>Open water field: freshwater, perennial streams, human-made ponds and Natural lakes</td>
<td>Dark blue</td>
</tr>
<tr>
<td>Built-up/ Urban area</td>
<td>BU</td>
<td>High populated areas may be cities, towns or conurbations; or Settlements, roads or any other kind of infrastructure.</td>
<td>Cyan</td>
</tr>
<tr>
<td>Forested/ Shrub wetland</td>
<td>FSW</td>
<td>Seasonally flooded areas covered with trees and shrub.</td>
<td>Deep Red</td>
</tr>
<tr>
<td>Emergent wetland</td>
<td>EW</td>
<td>Seasonally flooded areas covered with erect, rooted, herbaceous hydrophytes.</td>
<td>Green</td>
</tr>
<tr>
<td>Forest</td>
<td>FO</td>
<td>Areas covered with natural tree, such as coniferous trees and bush.</td>
<td>Dark Red</td>
</tr>
<tr>
<td>Farmland</td>
<td>FA</td>
<td>Cultivated areas with field crops rice, maize, beans or vegetables.</td>
<td>Pink</td>
</tr>
<tr>
<td>Bare Soil</td>
<td>BS</td>
<td>Soil or sand areas not covered by grass, sod or other live ground covers.</td>
<td>Dark Brown or Brown</td>
</tr>
</tbody>
</table>

When creating the training sites, many other reference maps were used to decide the pixel class besides the classification scheme above. The aerial photography was widely used as reference map because it has higher resolution than satellite imagery and it useful to detect small or long, narrow wetlands. Comparing with dry season imagery is another effective method to classify wetland types. Multi-temporal imagery often aids in classification of wetlands and their separation from other land cover classes. For example, there is a big difference in Canaan Valley National Wildlife Refuge images from May and September of 1999. The true ground photo shows that area should be wetland. In May 1999, it appeared a dark red tone that means the area was covered by healthy vegetation.
However, the red area in May declined and some of red area turned to brown in September 1999. There was no reason that the wetland disappeared dramatically just in 4 months. The only possible reason is that during the dry season, the emergent wetland dried up and deciduous forest species lost leaves in forested wetland.

Often vegetation indices can be useful for highlighting wetlands. The vegetation indices can be used in visual interpretation of wetland boundaries and extent or used in a classification algorithm to map wetlands and other landcover types. The normalized difference vegetation index (NDVI) is the most common used to measure vegetation cover. The reason NDVI is related to vegetation is that healthy vegetation reflects very well in the near-infrared part of the electromagnetic spectrum. The equation to produce the NDVI layer is:

$$\text{NDVI} = \frac{(\text{band 4} - \text{band 3})}{(\text{band 4} + \text{band 3})}$$

Negative values of NDVI (values approaching -1) correspond to deep water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Low, positive values represent shrub and grassland (approximately 0.2 to 0.4) whereas high values indicate temperate and tropical rainforests (values approaching 1). The typical range is between about -0.1 (for a not very green area) to 0.6 (for a very green area). With NDVI, it could help reducing the misclassification in emergent wetland. For example, the central area of Canaan Valley National Wildlife Refuge shows in a light brown and green tone and looks like a bare soil area. However, comparing with NDVI layer, the value shows around 0.5. That means that area has much more vegetation cover than barren area.
Figure 3.3: Examples of training sites that were selected for the land use and land cover classification in the 2002 image.

Spatiotemporal change of the images was the biggest challenge during classification. The classes identified varied from 1993 to 2002 because land use and land cover have dramatically evolved supposedly due to a rapid increase in population and agropastoral impacts on the landscape.

After clipping to match the Tucker county polygon, the classified images were then analyzed using ArcGIS 10.0 with additional shapefiles of transportation, river, population and DEM. All these shapefiles were converted to WGS84 UTM Zone 17N projection which matches the projection of the classified images. The attribute table containing class
information was exported to an Excel spreadsheet for calculation of the total area of each class by multiplying the number of pixels in the class by the spatial resolution of 30 x 30 m².

Accuracy assessment is an important part of any classification. With that, we could know how accurate our classification is. In this study, accuracy assessment was performed for all supervised classified wetlands. Some reference data reflecting the true land-cover were used to compare with classified map. Sources of reference data included ground truthing, higher resolution satellite images, and maps derived from aerial photo interpretation. The stratified random sampling method was designed to assess accuracy. Because every class needs about 50 random points to be collected, there were a total of 350 classified pixels to produce the classification accuracy for each image.
Chapter IV: Results

Classified Land cover and land use from 1993 to 2002

The total classified study area including Canaan Valley is about 30,857 acres.

During 1993, most of the area in Canaan Valley was pristine and undeveloped. About 56.17% of total area was wetland and 8.2% of the total area was forest (Table 4.1). 26.93% of the Canaan Valley land was exposed with no vegetation covered. Human activity areas, including urban area, farmland and built-up were nearly 8.51% of the total area.

<table>
<thead>
<tr>
<th>Canaan Valley Land Use</th>
<th>% of Total Area in 1993</th>
<th>% of Total Area in 1999</th>
<th>% of Total Area in 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>0.28%</td>
<td>0.29%</td>
<td>0.32%</td>
</tr>
<tr>
<td>Forested/Shrub wetland</td>
<td>52.46%</td>
<td>29.44%</td>
<td>23.84%</td>
</tr>
<tr>
<td>Emergent wetland</td>
<td>3.71%</td>
<td>3.47%</td>
<td>4.73%</td>
</tr>
<tr>
<td>Forest</td>
<td>8.20%</td>
<td>31.69%</td>
<td>25.33%</td>
</tr>
<tr>
<td>Farmland</td>
<td>0.97%</td>
<td>3.98%</td>
<td>2.46%</td>
</tr>
<tr>
<td>Built-up/Urban area</td>
<td>7.54%</td>
<td>30.42%</td>
<td>42.44%</td>
</tr>
<tr>
<td>Bare soil</td>
<td>26.93%</td>
<td>0.70%</td>
<td>0.89%</td>
</tr>
</tbody>
</table>

During 1999, forest covered 31.69% of the total Canaan Valley area and wetland covered 32.91%, which contained 29.44% of forested/shrub wetlands and 3.47% of emergent wetlands. Built-up/Urban areas were the third dominate land use with a dramatic increase in cover to 30.42% of the total area. There was a significant decrease in bare soil
relative to earlier data. Most areas initially classified as bare soil before were covered by urban area or major settlements. Farmland barely increased to 3.98% of total area.

During 2002, built-up/urban area became the first dominate land cover with 13097.26 acres representing 42.44% covered in Canaan Valley area. Despite the change, wetlands still were the second dominate land cover with 28.57% covered, but total area of wetlands continued to decrease from 1993 to 2002. Other areas, such as water, farmland and bare soil remained almost the same as in previous period.

**Land use and Land cover change from 1993 to 2002**

Vegetation change seemed different during dry and rainy season. For example, Figure 4.1 shows the difference in forested/shrub wetland change between the dry and the rainy season from 1993 to 2002. The total areas of forested/shrub wetland area were less in the dry season than the rainy season. Underestimation might be one possible reason. In 1993, there was a large difference between forest and forested/shrub wetland. However, this difference disappeared in 1999. There is no reason that the forest grew up so fast in six years except for misclassification. Some pixels in the forest class were probably misclassified as forested wetland class due to the difficulty of distinguishing forest and forested wetlands. This flip also happened between bare soil and built-up classes.

For comparison, this study used rainy season data to detect the land cover change. Land use of Canaan Valley has changed a lot from 1993 to 2002. The open water fields such as riverine, ponds and lakes occupied a tiny part of the land with about 0.3% cover. The water and farmland areas remained almost the same in over the nine years (Figure 4.1). There was a big change in built-up/urban, bare soil, wetland and forest areas. Both wetland and bare soil areas had a dramatic decrease whereas built-up/urban and forest increased. These changes can easily be seen in Figure 4.2 where the light green
represents wetland and dark green area is forest. From 1993 to 2002, these green areas were replaced by magenta and yellow areas, which represent urban and farmland respectively. Urban areas and the major settlements were the most developed land uses. In 1993, a small magenta urban area covered only 7.54%. However, the total urban area increased by 6 times from 1993 with the development of urbanization.

Figure 4.1: Land use change in Canaan Valley from 1993 to 2002

Wetland change from 1993 to 2002

There were big changes found in Canaan Valley’s wetlands from 1993 to 2002. But some changes could have been from misclassification as previously discussed. Table 4.2 shows the percentage of forested/shrub wetland changing to the other land covers. In 1993, 52.46% of the total areas were forested/shrub wetlands. 68.41% of these forested wetlands turned to forest areas in 1999. Because of potential misclassification for the uncertain reason, this difference does not necessarily represent actual wetland change. At the same time, bare soil and built-up classes were also combined into built-up/bare soil class. A change from the forested wetland category into this class is more likely to represent and actual wetland loss than a change from forested wetland to forest.
Figure 4.2: Land cover and land use change in Canaan Valley area from 1993 to 2002
In 1993, about 17,331.65 acres of wetland including forested, shrub and emergent wetlands were found, which represent 56.17% of total area in Canaan Valley (table 4.3). In 2002, only 8814.606 acres remained, about 28.57% of Canaan Valley area. Except the areas turning to the forest, total 4398.339 acres of wetland were lost during this nine years interval from 1993 to 2002. These data mean about one-fourth of the wetlands were lost by 2002. Most wetland loss occurred in the south area (Figure 4.3). Canaan Valley National Wildlife Refuge in the north kept the main wetland.

Forested/shrub wetland and emergent wetland changed differently in this 9-year period. There was a significant loss in forested wetlands. In 1993, there were 16187.65 acres of wetland covered by forest trees and shrub, which was the dominate wetland type in Canaan Valley. But by 2002, only half of the total area of forested/shrub wetlands remained (Table 4.3). At the same time, emergent wetland had a slight increase by the end of 2002. The total area of emergent wetland was about 1459.13 acres, which represent 16.6% of total wetland Canaan Valley area.

Table 4.2: Percentage change of forested/shrub wetlands changed into other land uses

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% of 1993 forested wetland turned into</td>
<td>% of total study area</td>
</tr>
<tr>
<td>Forest</td>
<td>68.41%</td>
<td>35.89%</td>
</tr>
<tr>
<td>Farmland</td>
<td>0.06%</td>
<td>0.03%</td>
</tr>
<tr>
<td>Built-up/ Bare soil</td>
<td>30.28%</td>
<td>15.88%</td>
</tr>
</tbody>
</table>
Table 4.3: Wetland change from 1993 to 2002

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>Total Area in 1993</th>
<th>Total Area in 1999</th>
<th>Total Area in 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forested/ Shrub Wetland</td>
<td>16187.65</td>
<td>9084.815</td>
<td>7355.476</td>
</tr>
<tr>
<td>Emergent wetland</td>
<td>1143.997</td>
<td>1071.497</td>
<td>1459.13</td>
</tr>
<tr>
<td>Total wetland</td>
<td>17331.65</td>
<td>10156.31</td>
<td>8814.606</td>
</tr>
</tbody>
</table>
Figure 4.3: The trend of wetland loss from 1993 to 2002
Accuracy Assessment

The overall accuracies were very high as observed in Table 4.4; they ranged from 86.21% to 91.72% with a Kappa index of 0.82 to 0.90. Higher producer’s accuracy means more pixels on the original image were correctly classified for a given class in reference plots. Higher user’s accuracy means more pixels on the map were actually classified into a given class. Both water area and farmland area had a very high producer’s and user’s accuracy, which shows this classification did well to detect water and farmland area. The producer’s accuracy of forested/shrub wetland and forest in 1993 were very low: 62.5% and 76.19. That’s probably due to the confusion between these two land cover types.

Table 4.4: Results of accuracy assessment of classified images from 1993 to 2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Accuracy %</th>
<th>WA</th>
<th>FA</th>
<th>FO</th>
<th>BU</th>
<th>FSW</th>
<th>EW</th>
<th>Overall %</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1993</td>
<td>User</td>
<td>91.72</td>
<td>82.22</td>
<td>68.11</td>
<td>91.5</td>
<td>78.65</td>
<td>90.46</td>
<td>86.21</td>
<td>0.82</td>
</tr>
<tr>
<td></td>
<td>Producer</td>
<td>100</td>
<td>93.75</td>
<td>76.19</td>
<td>87.5</td>
<td>62.5</td>
<td>95.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>User</td>
<td>80</td>
<td>84.21</td>
<td>81.52</td>
<td>93.47</td>
<td>80.28</td>
<td>92.5</td>
<td>88.34</td>
<td>0.86</td>
</tr>
<tr>
<td></td>
<td>Producer</td>
<td>95.83</td>
<td>80</td>
<td>90.91</td>
<td>66.67</td>
<td>95.83</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>User</td>
<td>100</td>
<td>92.86</td>
<td>79.43</td>
<td>94.25</td>
<td>84.12</td>
<td>88.58</td>
<td>91.72</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Producer</td>
<td>100</td>
<td>89.66</td>
<td>84.21</td>
<td>70.43</td>
<td>88.89</td>
<td>71.43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(WA= Water, FA= Farmland, FO= Forest, BU= Built-up/Urban area, FSW= Forested /Shrub wetland, EW= Emergent wetland)
Chapter V: Discussion and Conclusion

Significant change has been detected in the Canaan Valley area with high accuracies. There was a serious wetland loss from 56.17% in 1993 to 28.57% in 2002 in Canaan Valley area due to the dramatically decrease in forested/shrub wetland. The remaining total wetland area was estimated only 8814.606 acres by 2002, which was about half of wetland in 1993. The dominant wetland type was still forested/shrub wetland. Emergent wetland occupied a small amount with 16.6% of total wetland area. The Canaan Valley National Wildlife Refuge kept the main wetland. Both dry season (see in Appendix) and rainy season data show this big decrease happened in south part of Canaan Valley area. The disappeared wetland was replaced by urban area. From 1993 to 2002, urban area increased from 7.54% to 42.44% of total Canaan Valley area.

A lot of human actions lead to this wetland change such as developing urban area, tilling for crop production, and building a transportation system. It’s clear to see that the major wetland area remained is in the east part of Tucker County, which is far away from the cities and roads network (Figure 5.1).

Urbanization is a major cause of wetland loss. With increased population, more and more areas need to be extended for human activities. For many years, the value of wetland was underestimated. Roads and bridges are frequently constructed across wetlands since people thought wetlands have low land value. It is often considered to be more cost effective to build roads or bridges across wetlands than around them. Road and bridge construction activities can increase sediment loading to wetlands. Rock salt used for deicing roads can damage or kill
vegetation and aquatic life. It shows there is almost no wetland around the intensive roads network. Also the wetland near the Windwood Fly-in Resort airport has decreased since 1992.

Adding man-made surfaces like cement increases runoff pollution into wetlands. Other anthropogenic pollutant will cause wetland vegetation damage and result in wetland loss, examples are air pollution from cars, factories and power plants, toxic substances from landfills and dumps, water pollution from industries and agriculture. The highly populated cities in Tucker County have fewer wetlands around. Plants in wetland were removed in order to use land for other human purpose.

Digital classification of wetlands is significantly useful in identification and labelling of the land cover classes. Time series data are essential in determination of the classes. The resolution of the images matters a lot for appropriate classification of the wetland uses and cover. The thematic maps produced portray the diverse ways in which small wetlands are utilized. With the high overall accuracies which were closed to 90%, the wetland classification was properly done. Even if there were a few classes with low accuracies due to some reasons, that didn’t affect the overall accuracies and final classification. However, there were some limitations in this study. Because of the limitations of Landsat imagery as the primary data source to detect some wetlands, certain wetland types were excluded from this monitoring effort. Other limitations included the inability to detect small wetland areas, inability to accurately detect or monitor certain types of wetlands that may require hyperspectral or other specialized imagery or analysis techniques (Dierssen et al., 2003, Peneva et al., 2008), and inability to consistently identify certain forested wetlands either because of their small size, canopy closure, or lack of visible hydrology. In this way, ground collection of the land cover and land use data would be
more reliable for wetland analysis. But the process of ground collection is very complicated and
time consuming. During the classification process, although the true color aerial photography
and other maps and techniques were used as reference data to show evidence of distinguishing
the different land use and land cover classes, identifying each class relied on the author’s
knowledge of the study area and from past field work. Some pixels might not be classified or
misclassified. But with the high accuracies, the results are still reliable. For future study, the dry
data can be used in a comparison study with the rainy data to detect the rainfall effect on
wetland classification. Moreover, the results can also contribute to the West Virginia wetland
protection program.
Figure 5.1: Wetland of Tucker County in 2002
Bibliography


ESRI. 2007. ArcGIS 9.2 Environmental Systems Research Institute, Inc. GIS Software


West Virginia Wetland Program Plan. 2011. *West Virginia Department of Environmental Protection, and West Virginia Division of Natural Resources*. 
Appendix

Land Cover and Land Use in Canaan Valley Area

Appendix 1: Land cover classification in dry season from 1992 to 2005
Appendix 2: Wetland loss in dry season from 1992 to 2005
Office of Research Integrity

March 14, 2013

Yisha Shi
620 15th Street
Apt. 17
Huntington, WV. 25701

Dear Yisha:

This letter is in response to the submitted thesis abstract titled “A Remote Sensing and GIS Based Wetlands Analysis in Canaan Valley, West Virginia.” After assessing the abstract it has been deemed not to be human subject research and therefore exempt from oversight of the Marshall University Institutional Review Board (IRB). The Code of Federal Regulations (45CFR46) has set forth the criteria utilized in making this determination. Since the information in this study does not involve human subjects as defined in the above referenced instruction it is not considered human subject research. If there are any changes to the abstract you provided then you would need to resubmit that information to the Office of Research Integrity for review and a determination.

I appreciate your willingness to submit the abstract for determination. Please feel free to contact the Office of Research Integrity if you have any questions regarding future protocols that may require IRB review.

Sincerely,

Bruce F. Day, ThD, CIP
Director
Office of Research Integrity

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