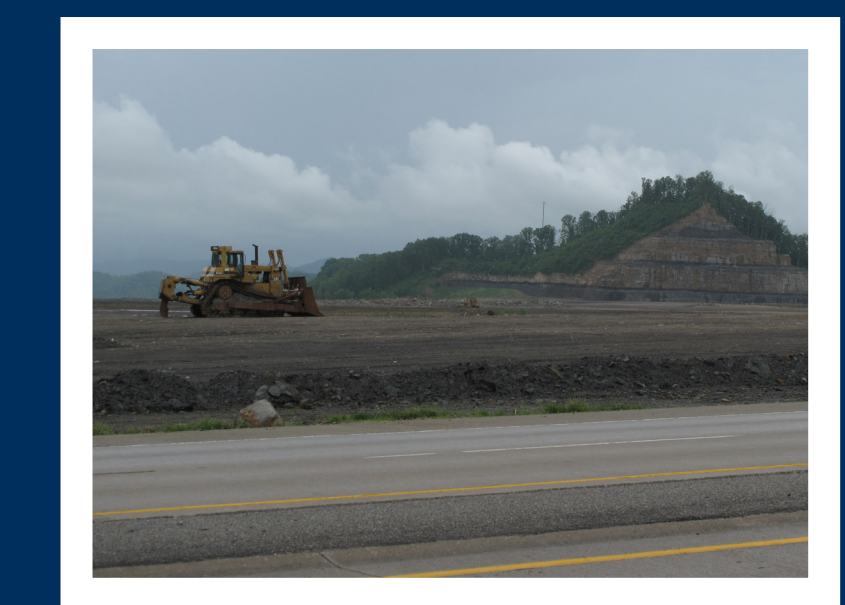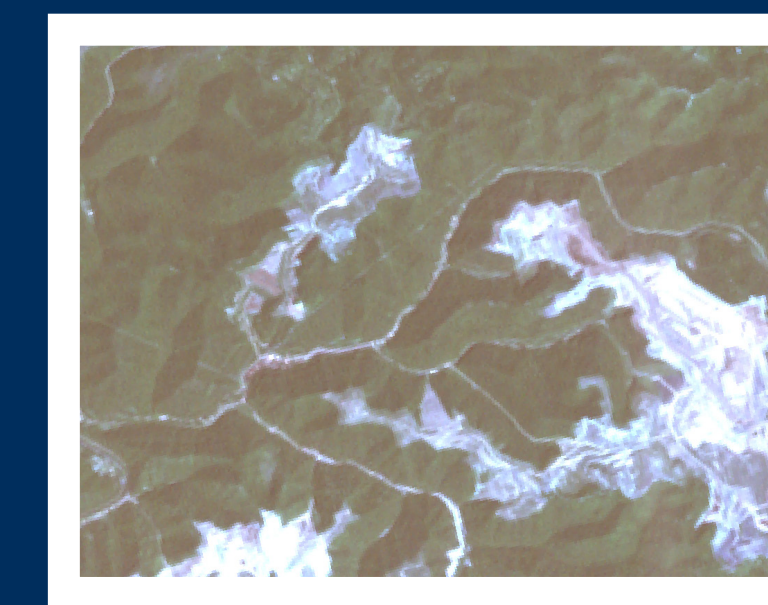# MOVING MOUNTAINTOPS
Monitoring Surface Mine Expansion and Reclamation Using Landsat Imagery

Introduction

Mountaintop removal is a heavily mechanized surface mining practice characterized by the removal of rock and dirt (called overburden) to expose underlying coal seams. After the coal is extracted, excavated overburden is subsequently deposited in adjacent valleys. Extensive surface mining operations are located throughout the Appalachian Region, with especially high concentrations in southern West Virginia.

While active surface mine extent peaked just prior to the Surface Mining Control and Reclamation Act of 1977[1], the practice remains highly controversial in light of its acute cultural and environmental impacts.
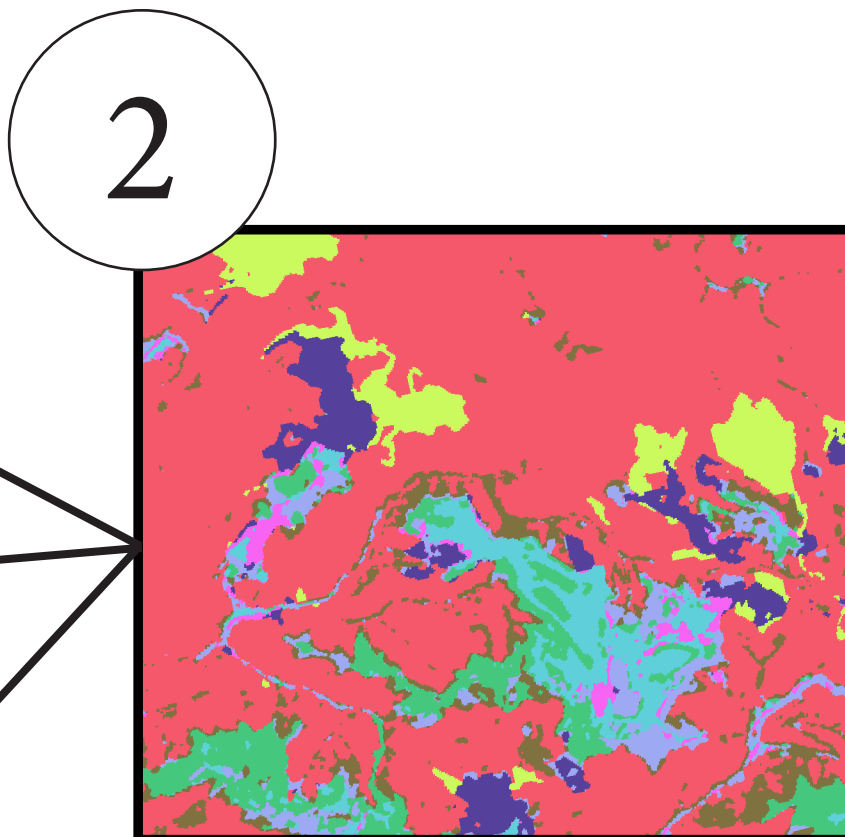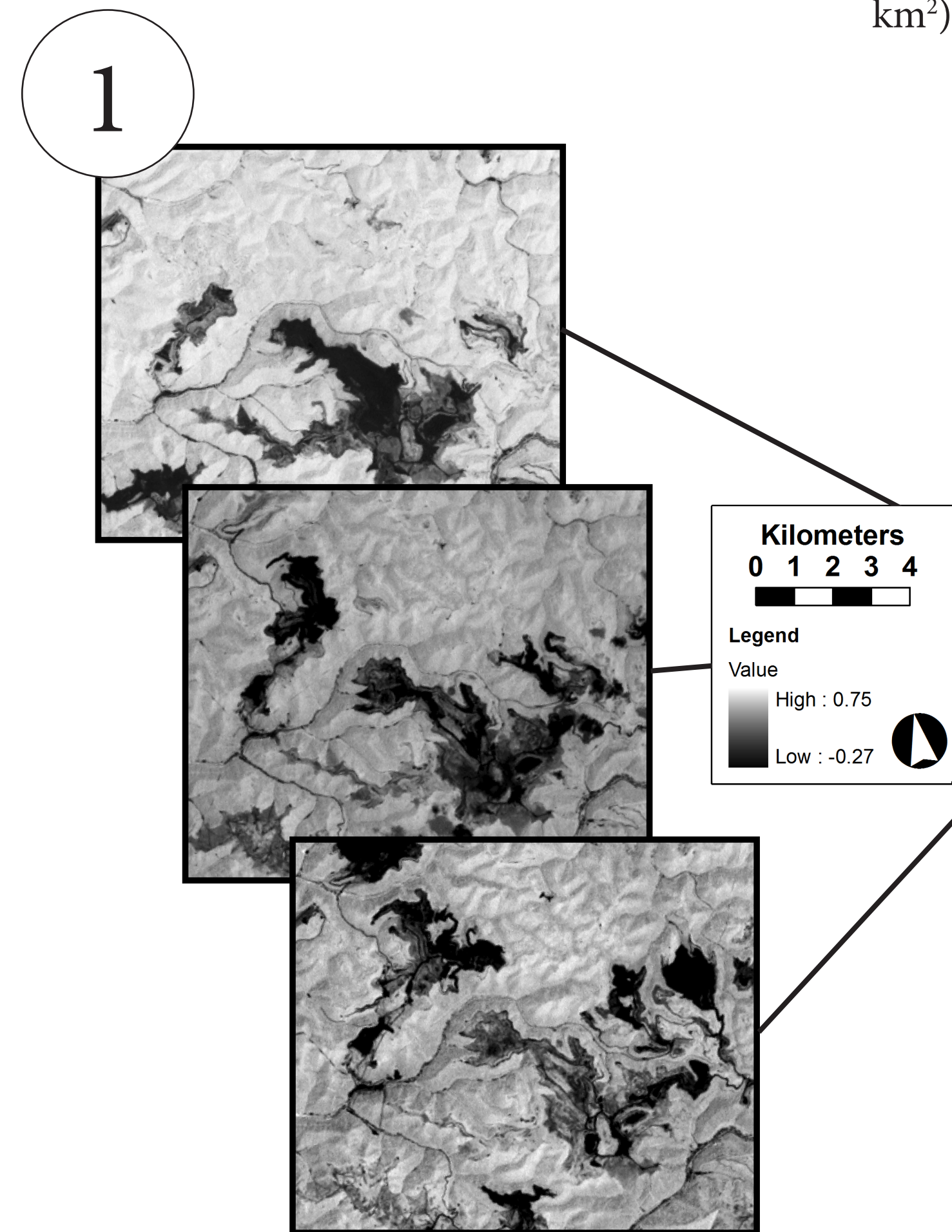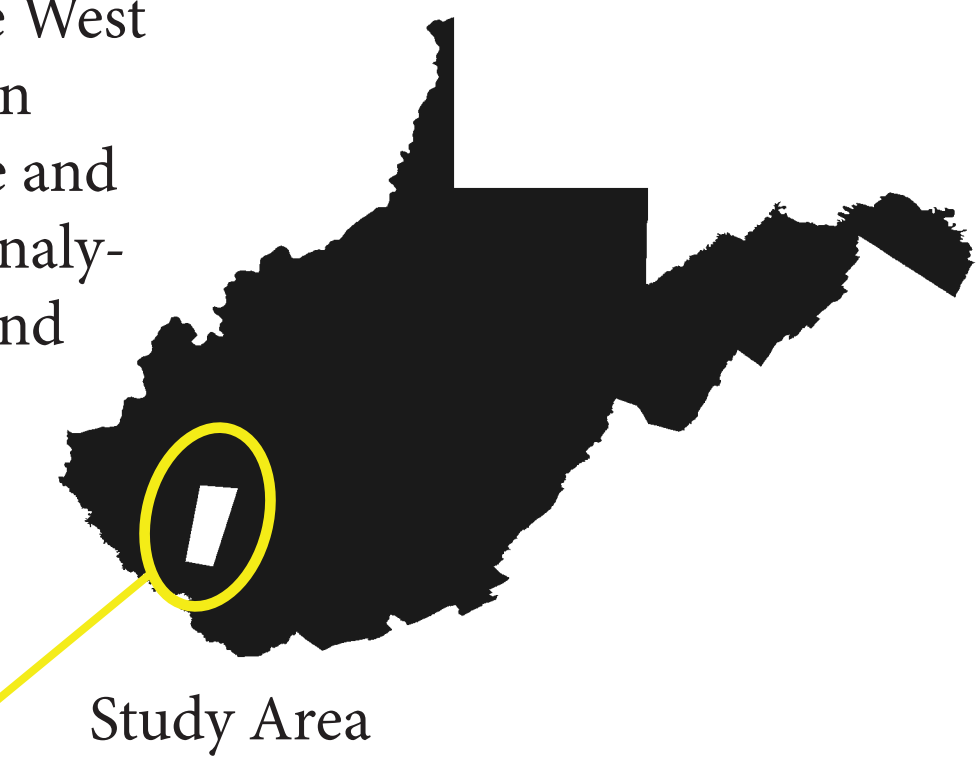
Remote sensing analysis of Landsat imagery offers a a cost-effective method to monitor surface mine expansion and reclamation over time. During the first 6 years of the 11 year study period (1999-2005), the extent of active mining outpaced mine reclamation, but reclamation increased more rapidly from 2005-2010 (see graph below). Disturbances due to mining, both past and present, are estimated to cover 20% (149 km^2) of the study area in 2010.

Image Acquisition, Preprocessing, and NDVI Analysis

Three near anniverary date Landsat 7 ETM+ images were acquiredfrom the USGS Landsat archive[2]. A 729 km^2 study area was cropped from the orignal images to eliminate data gaps present on post-2003 (SLC-off) Landsat images.

Normalized Difference Vegetation Index (NDVI) images were calculated for Landsat image to compare vegetative cover and health over the three image time series (see above images). In general, areas with low NDVI values (dark) correspond with active mines, midrange values with reclamation areas, and high values (white) with undisturbed forest.
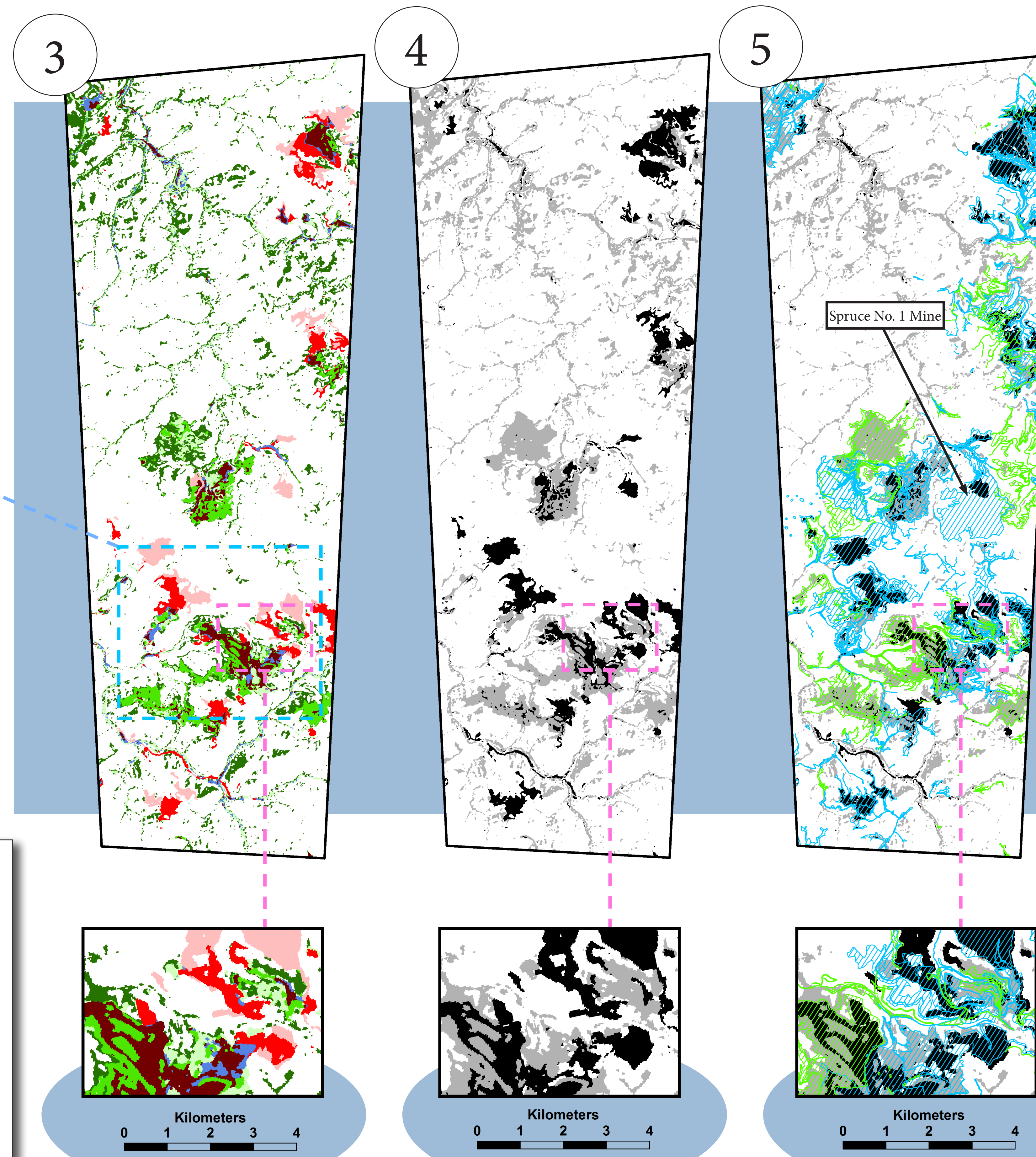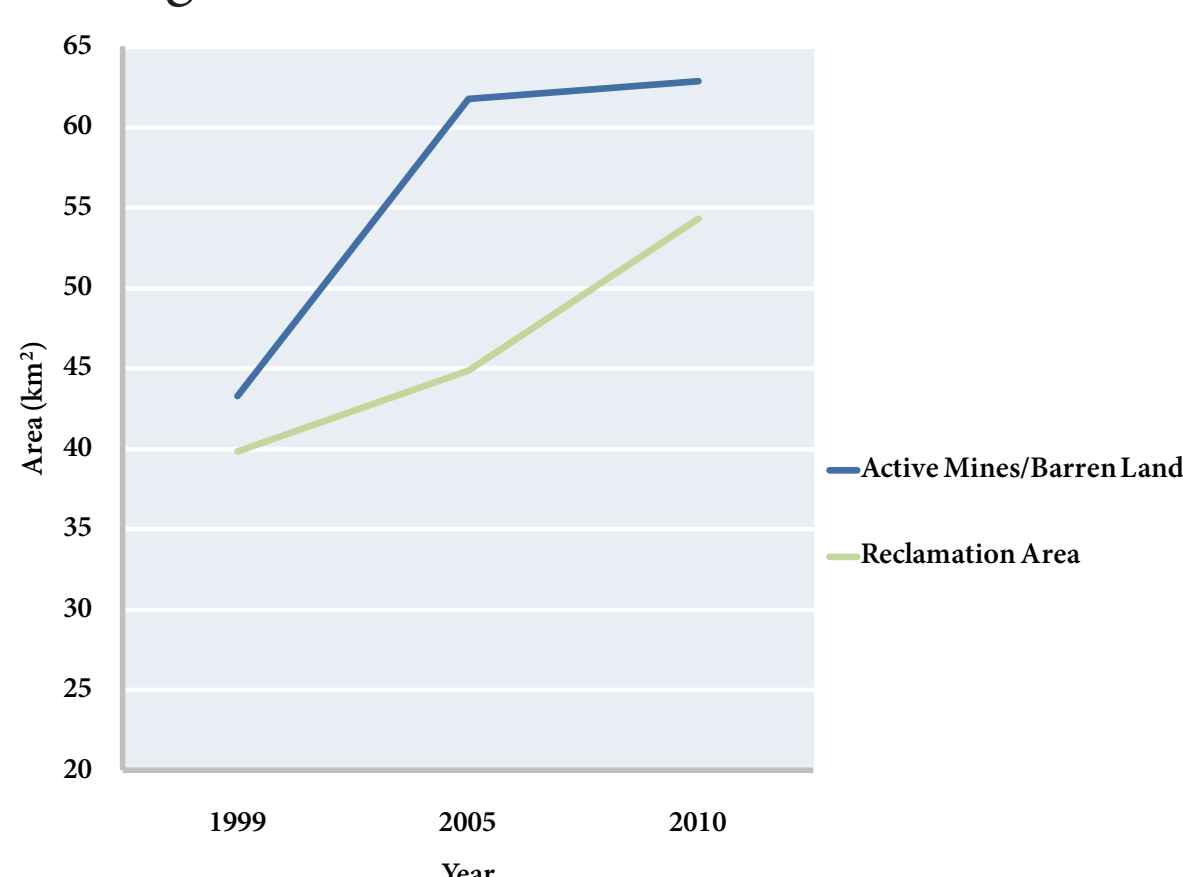
Unsupervised Classification

The resultant NDVI bands for each study year were combined into a single, three-band image. An unsupervised classification using a K-means clustering algorithm was run to group the pixels into ten classes. The resulting classification (shown above) was overlaid on the original Landsat color composites to interpret suface cover types represented by each class.

Time Series Classification

Classes generated from the unsupervised classification were merged into eight distinct groups (below, left). Three were used to categorize temporal changes in land cover from active mines, including those existing before 1999, as well as expansions over the two time intervals. No obvious temporal pattern could be deciphered in the three classes comprising reclamation areas. Instead, the three groups were interpreted to correspond with low, medium, and high vegetative growth and density. Despite significant revegetation, reclaimed mines were still readily distinguishable from the surrounding forest for the duration of the 11 year study period. A simplified classification is shown below (right).

Comparing with Permit Boundaries

A visual evaluation was conducted by comparing the results of the unsupervised classifcation with a mining permit boundary datalayer maintained by the West Virginia Department of Environmental Protection (WVDEP) [3]. As shown in the figure below, active and reclaimed mining areas delineated through this analysis were within the WVDEP permit boundaries and corresponded with the expected permit status.

Study Area

Changes in Active and Reclaimed Mine Area

Spruce No. 1 Mine

Legend

Active Mine/Barren Land
- Existing
- Expansion 1999-2000
- Expansion 2005-2010

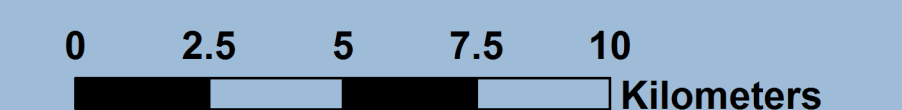**Reclaimed Mine Status**
- Low
- Medium
- High

Other
- Forest
- Water

Land Cover
- Active Mine/Barren Area
- Reclamation Area
- Forest/Other

Permit Boundary and Status
- Active Mining Area
- Mine Reclamation Area

Kilometers
0 2.5 5 7.5 10

Projected Coordinate System: NAD 1983 UTM Zone 17N

Data and Image Sources

[1] Townsend et al. (2009) Changes in the extent of surface mining and reclamation in the Central Appalachians detected using a 1976-2006 Landsat time series. Remote Sensing of Environment, 113, 62-72.

[1] NASA Landsat Program. Images acquired through the USGS online Earth Explorer application.

[3] WVDEP. (2008). Mining Permit Boundaries. Available at gis.dep.wv.gov

* All photographs by the author.

Dan Nally • Tufts University • Spring 2011