Mountain Top Removal Mining

Detecting Change in West Virginia

Mountain top mining site in reclamation near Kirk, WV[1]


Samples Mine, Mountaintop Removal Mine, West Virginia. Oct. 16, 2008[2]

Introduction

According to the USGS, surface mining is the largest cause of topographic change in the United States. This project serves to demonstrates the use of remote sensing techniques in assessing environmental changes caused by one type of surface mining, Mountaintop removal mining (MTR). We will look at a vegetation loss at a mining site in West Virginia, as well as topographic changes caused by this mining technique.

Mountaintop mining is a used to expose coal seams for processing on steep terrain in the Appalachian region of the United States. The process begins with the clear cutting of large swaths of land, removing all vegetation. Rock is typically displaced by blasting, either removing the top or a ridge from a mountain. This can result in as much as 400 feet of elevation change. The blasted rock, the "spoil" is usually dumped into adjacent valleys creating "valley fills". These valley fills have proven to have environmental impact on local watersheds.[3] Finally, with the mountain now opened, exposing the coal seam, the processing of coal can begin. Upon completion of mining operations, the area is reclaimed/ replanted with new vegetation, sometimes attempts are made to restore the original contours

Study Site

For examining regional change, the area defined by the WV Geological and Economic Survey as the "Approximate region of present and projected major mountaintop removal mining activity" was selected. A mine specific site to look at in greater detail for both NDVI and topographic change was also identified. For this purpose, the Twilight MTR site, located in Boone County West Virginia owned by Progress Coal (Massey Energy) was used because of its permitting date, active operation and massive production.

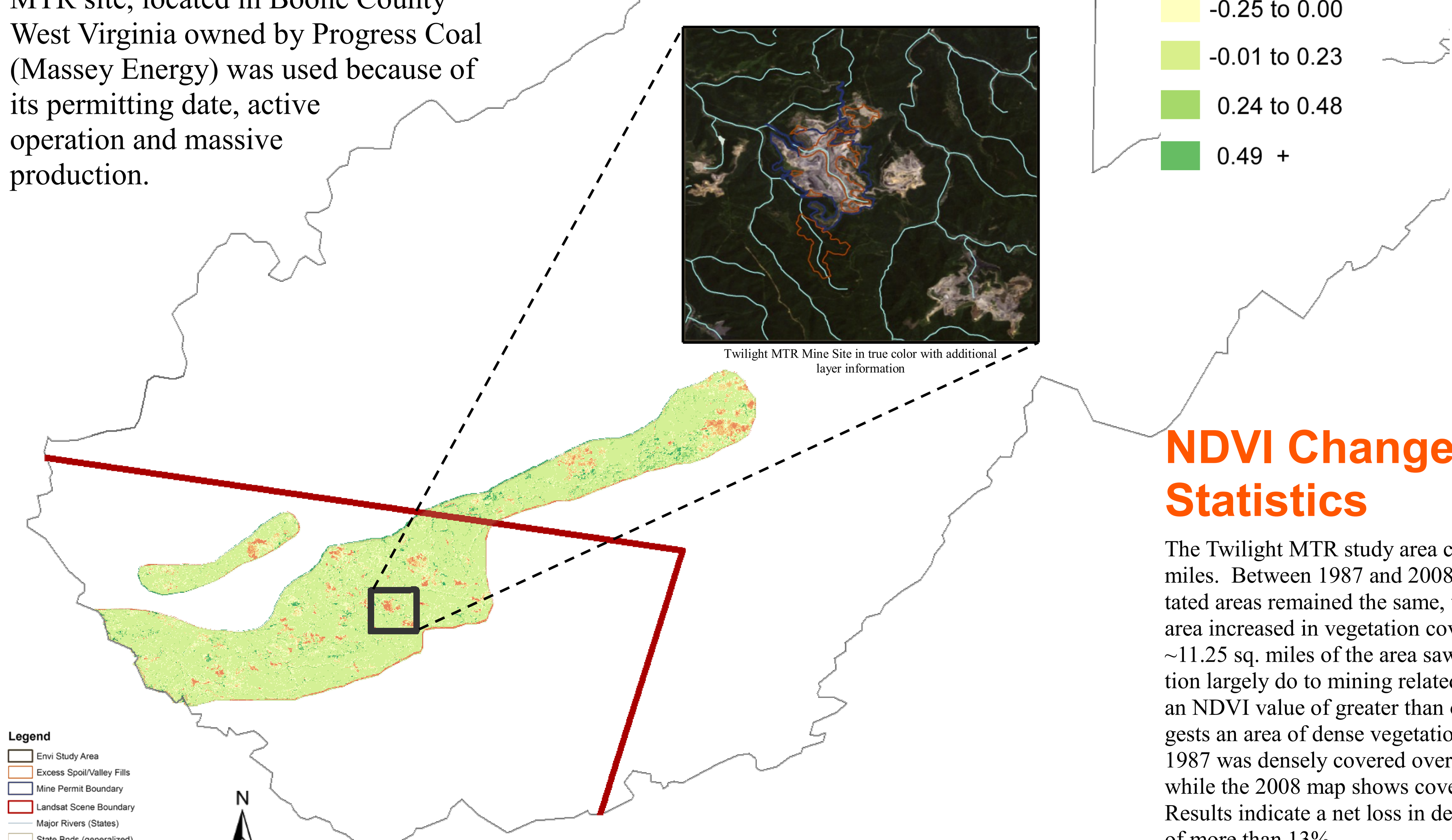
Project Data

Prior to beginning analysis, Landsat 5 Thematic Mapper (TM) images were obtained using the USGS EarthExplorer, this satellite was chosen because it offered a long-term look at the study area. The images are generally from the same time of year (May-July), although obtaining exact anniversary images was not possible. They were also chosen because of their minimal cloud cover, and good weather. Images were then clipped using an ENVI ROIs created from an ArcGIS shapefile. DEMs for topographic comparisons were also obtained. The older DEM was published in 1999, and is a 30 meter per pixel National Elevation Dataset (NED) clipped to WV's state boundaries, with elevation recorded in meters. This data was further clipped with the previously established Study Area ROI seen in the state map below. The second DEM obtained was a 3 meter per pixel model published by the State of WV in 2003, these conform to the USGS 7.5 minute quadrangle series, elevation in this DEM was recorded in feet. Additional Landsat 5 tiles for creating a regional NDVI difference map were also obtained.

NDVI

Normalized Difference Vegetation Index is a means for measuring density of vegetation, values range from –1 to 1 with 0 indicating no vegetation. This formula takes advantage of the fact that vegetation absorbs visible light in the red band, and reflects strongly in the near infrared.

$$\text{NDVI} = \frac{\text{NIR - R}}{\text{NIR + R}}$$



Twilight MTR Mine Site in true color with additional layer information

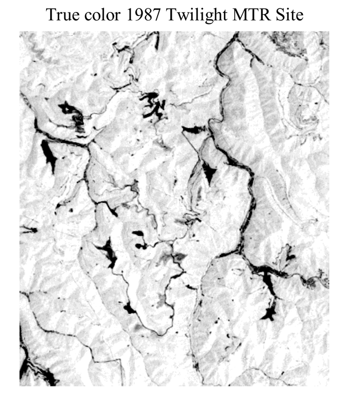
Pictured above: Regional NDVI difference between 1988 and 2008, with mine sites scarring the landscape

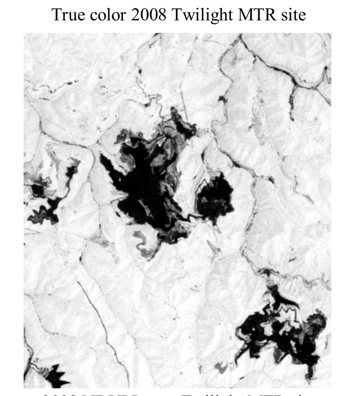
NDVI Change Detection Methods

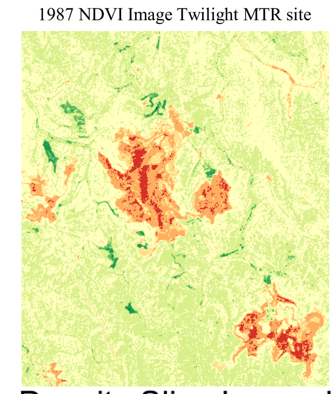
NDVI images were created for the mine site study area using Landsat data from 1987 and 2008. Five control points were selected visually in areas where there was suspected to be no change, and a constant value was calculated as the average difference over the five points. This constant was added to the values on the image with the lower raw values.


True color 1987 Twilight MTR Site


True color 2008 Twilight MTR site


1987 NDVI Image Twilight MTR site


2008 NDVI Image Twilight MTR site



Density Slice Legend

- < -0.74
- -0.68 to -0.49
- -0.49 to -0.24
- -0.25 to 0.00
- -0.01 to 0.23
- 0.24 to 0.48
- 0.49 +

To the left is a density sliced NDVI difference image of the Twilight MTR site. Density slicing was used to classify the images for data extraction in ENVI.

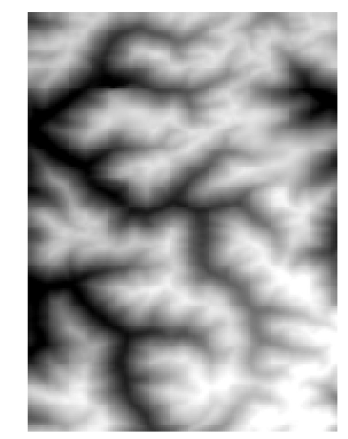
The density slices to the left represent the NDVI difference between the 1987 and 2008 at the Twilight MTR site. The state map of West Virginia depicts a general picture of NDVI lost in the main region that encapsulates Mountain Top Mining activity over the same period.

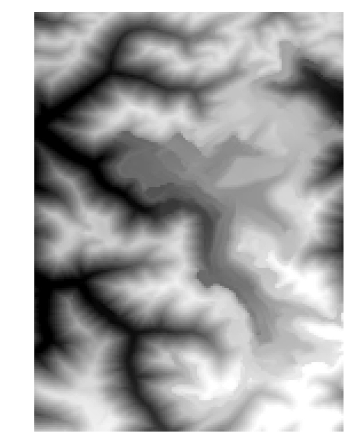
NDVI Change Statistics

The Twilight MTR study area consisted of 62.7 sq. miles. Between 1987 and 2008, 77.717% of vegetated areas remained the same, while 3.322% of the area increased in vegetation coverage. 18.96% or ~11.25 sq. miles of the area saw a decrease in vegetation largely do to mining related activities. Assuming an NDVI value of greater than or equal to 0.6 suggests an area of dense vegetation, the study area in 1987 was densely covered over 93.78% of its area, while the 2008 map shows coverage of only 80.45%. Results indicate a net loss in densely vegetated areas of more than 13%.

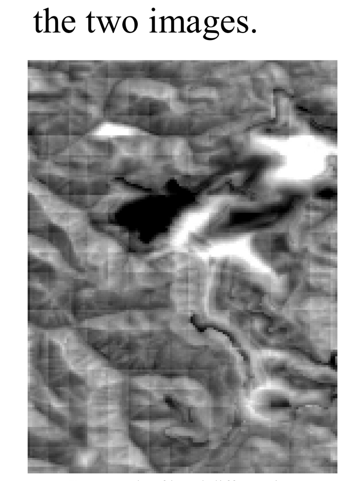
DEM Differencing

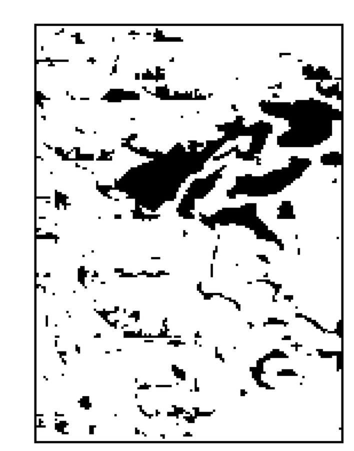
In an attempt to quantify the topographic changes caused by mountaintop removal and valley fills, digital elevation model (DEM) differencing was examined as a technique for capturing this change. First, two DEMs were selected with enough temporal distance to show the effects of the mining activity. For clarity these DEMs were clipped to the mining permit area for the Twilight MTR surface mine site identified earlier.


1999 DEM


2003 DEM

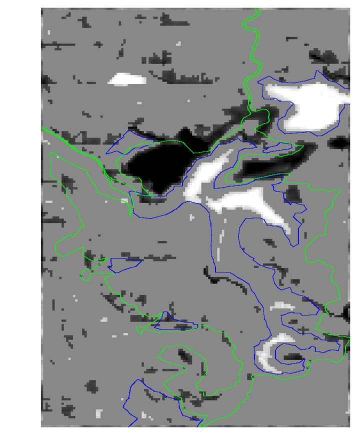
Just looking at the two unprocessed DEMs side-by-side, the fact that change has occurred is obvious in the center of the images. In addition to the ROI clipping, the 2003 DEM was re-projected from UTM to Lat/Long to match the 1999 model. The 1999 data represented 30 meters per pixel while, the 2003 data represented 3 meters per pixel. The 2003 data was re-sampled to match the 1999 model once again. Both DEMs originated with the same datum. The 1999 DEM was converted from meters to feet using band math so that elevation units would match between the two models. Finally, registration was checked between the two images, and a best effort was made to identify 5 control points, and register the DEMs. With preprocessing complete, band math was used to difference the two images.


Raw result of band differencing

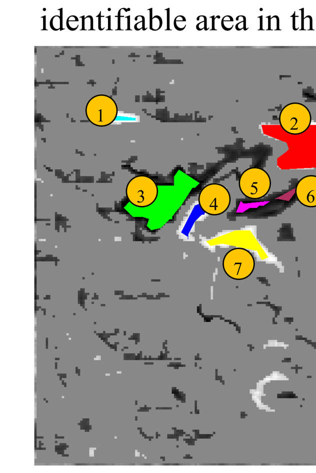

Segmentation Image

Due to what I believe to be a combination of registration and re-sampling issues. Comparing a 3 meter and 30 meter DEM may be too dramatic a difference to produce a highly accurate result after re-sampling. The raw difference of the two DEMs produces a stereo effect. However, it also produces the desired results showing clear elevation changes in black and white in the above image. A segmentation image was created to threshold all changes less than 50 feet in gain or loss, this image was than inverted to create a mask to help bring out the mining related changes we were interested rather then processing noise.


Mask Image


Masked difference with overlays

Above, on the left is the mask image generated from the segmentation image. This mask was than applied to the difference image to produce the image on the right. Vector layers were than added to the image with the green representing the mining permit boundary, and the blue representing valley fill permit areas. Five years into mining operations the valley fill area on the left is showing dramatic elevation gains. The permit boundaries show that this method is fairly accurate for identifying topographic change due to mountain top removal mining and valley fills. Finally, ROIs were added to the masked image, and converted to classes so that elevation changes for each identifiable area in the mine could be recorded.

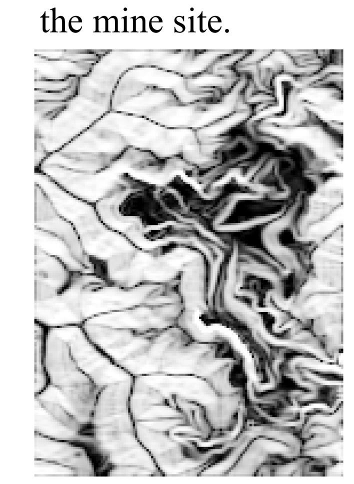


Recorded Elevation Changes (feet)	
Site 1	+408
Site 2	+575
Site 3	-496
Site 4	+284
Site 5	-277
Site 6	-223
Site 7	+301

One thing to note is that the need for the segmentation image suggests the accuracy of the results to be only within 50 feet of the actual change.

Topographic Modeling

ENVI's topographic modeling features were also employed to visually compare the two DEMs for the mine site.


2003 Slope Image


2003 Shaded Relief Map

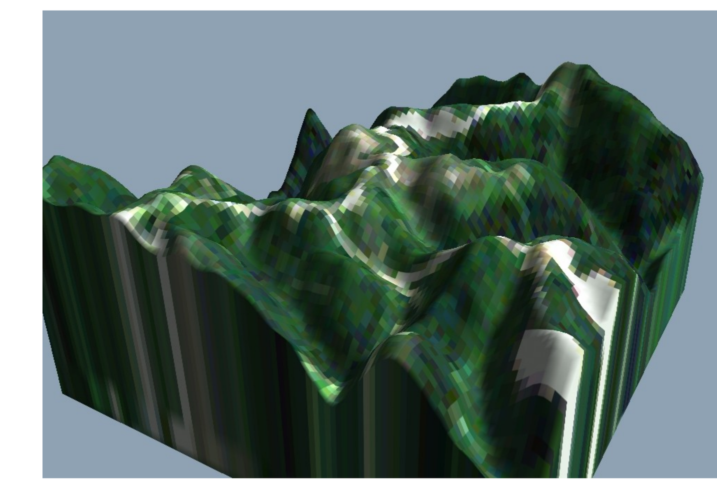

1999 Slope Image


1999 Shaded Relief Map

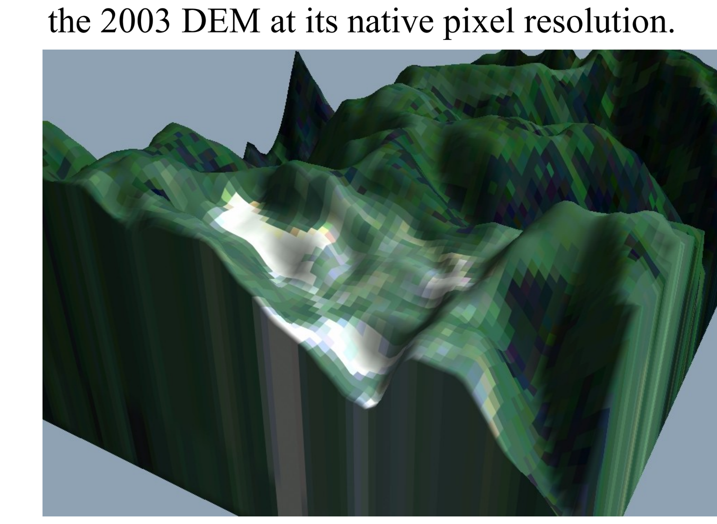
Both 1999 maps have been filtered with a smoothing filter to remove the grid pattern. Both topographic modeling features prove useful for visually comparing the DEMs although computationally comparing the two would be difficult.

DEM Surface Modeling

In order to look at the topographic change in a way that may be more meaningful to someone not used to dealing with remotely sensed data 3D surface projects were next created. While ENVI provides these tools, the 3D models displayed here were created with the software 3DEM. For the first model, the 1987 Landsat 5 image was saved as a 3 band true-color geotiff,


1999 DEM draped with 1987 Landsat 5 true color image. Twilight MTR site would be located near front and center.

Next, the 2008 Landsat 5 data was draped over the 2003 DEM at its native pixel resolution.


2003 DEM draped with 2008 Landsat 5 true color image. Twilight MTR site located near front and center, peaks in that area now flattened.

Looking at the two 3D models side-by-side, the topographic changes in the area of the mining site is now obvious. If the effects were not clear from the quantified data in the DEM differencing results they certainly visually apparent in these models.

Conclusions

Vegetation change in the mining site areas is dramatic and so it is somewhat obvious to detect the changes regardless of the method used. However, calculating the NDVI values and classifying the image allowed for quantifying the loss. Ultimately, the same results could have probably been achieved with supervised classification. Seeing this magnitude of topographic change in the U.S. is interesting, and unique. Differencing DEMs appears to be a viable way for identifying valley fills and surface mining operations, despite its limitations. Looking back at the original 1987 Twilight MTR Landsat scene, there's clearly a lot of water flow in the surrounding area that is either now gone or diverted due to mining. These may be seasonal flows and the July timeframe was too late to capture them in the 2008, or this may be an effect of mining at the site. Looking into the waterway impacts would be an interesting area to have follow up on.

References:

[1] Mountain near Kirk, WV. Photography retrieved from http://www.flickr.com/photos/13155199@N08/sets/72157601942027539/detail/ - cc license
[2] MTR_Panorama, Mountaintop Mining. Photography. Retrieved from http://www.flickr.com/photos/22461074@N04/2960945511 - cc license
[3]Palmer MA, Bernhardt ES, Schlesinger WH, Eshleman KN, Foufoula-Georgiou E, Hendryx MS, et al. (2010) Mountaintop mining consequences. *Science* 327:148–149.
Significant topographic changes in the united states. (2008, August 25). Retrieved from http://topochange.cr.usgs.gov/mining.php
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