

Analysis of Land Cover Change within Historically Abandoned and Reclaimed Mine Land Surrounding Centralia, Pennsylvania

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Abstract:

Historically, coal mining has been one of the most dominant driving forces of land cover change in Pennsylvania. Abandonment of mining lands leads to environmental impacts, such as acid mine drainage, and can have implications on human health. In order to minimize impacts from abandoned mine lands, the Abandoned Mine Land Reclamation Act of 1977 was established, which required mining companies to reclaim abandoned mines after 1977. One site that has been highly influenced by coal mining is the Centralia region of Pennsylvania. The goal of this study is to quantify the types and amounts of land cover change within historically abandoned mine lands in the Centralia region. Historic aerial photographs from 1939 were georeferenced and surface mines and tailing piles were delineated. The Chesapeake Bay Land Cover Datasets from 1984 and 2006 were then overlaid with the digitized historic mine polygons in order to calculate the amounts of types of land cover change within the mined lands. The analysis revealed that the majority of the abandoned mine lands have transitioned to other land cover types, such as deciduous forest, which is the dominant land cover type within the abandoned mine land polygons. The study also found a 70% decrease in mined land from 1937 to 2006, with approximately 18% of the study area remaining barren. Despite this, only 4% of the mines in study area have been reclaimed. This study can assist in an evaluation of the composition of the land cover in the anthracite fields of Pennsylvania.

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1.0 Introduction:

Examination of land cover change over time is crucial in understanding the long-term environmental impacts created by anthropogenic disturbances. One such disturbance is the mining of natural resources. Conversion from natural land to mined land impacts biodiversity by fragmenting and destroying habitat, and alters the hydrologic regime of a watershed (Townsend et al. 2009). Surface mining is one of the dominant drivers of land use change in the Central Appalachian Mountain region of the Eastern United States. In Pennsylvania, surface mining of coal is the largest and most common form of land disturbances (Townsend et al. 2009). Coal has formed a long part of Pennsylvanian history and continues to compose a large portion of Pennsylvanian jobs and industry (PELSP 2011). Due to the nature of the coal extraction process, large areas of land have been disturbed for many decades, as overburden is removed and the tailings are piled across acres of land (Demirel et al. 2011). In many cases, historical mines were abandoned after becoming economically unviable.

Within Pennsylvania, there are approximately 250,000 acres of mine lands that were abandoned before the establishment of regulations that called for reclamation of these lands to a pre-mining state (PADEP 2015A). Historically abandoned mine lands continue to impact the surrounding landscape and environment. Often these environmental issues become externalities in the mining process and are left for future generations to fix. Along with environmental issues, there are also issues associated public health. For example, stripping pits can become dangerous areas resulting in injuries or deaths from high wall cave-in. Tailing, left following the end of a mining operation, can cover large tracts of land created risks of landslides. Reports even suggest that the dark waste can heat enough to ignite forest fire (DEP 2015A). In addition, the exposed pyrite rich tailings have resulted in a decrease of water quality from the production of acid mine drainage (AMD) (Urban 2012). Even underground mines can result in a change in the landscape. Cropfalls, or subsidence from underground mine collapse, have become a serious issue that is resulting in the loss of hundreds of acres within the Pennsylvania Anthracite fields (Koury 2015).

Analyzing land cover change in abandoned mine lands can assist in understanding the dominant trends in mine land conversion over time and can identify areas that might require

future attention from conservation and remediation. The purpose of this study is to understand the dominant trends in land cover change within abandoned mine lands in Centralia, Pennsylvania and the surrounding area between 1939, 1984, and 2006. The overall goal is to quantify the types and amounts of abandoned mine land cover that has been converted or reclaimed.

2.0 Background:

2.1 The Surface Mining Control and Reclamation Act of 1977

In order to mitigate the environmental issues associated with coal mining, the United States Department of Interior issued the Surface Mining Control and Reclamation Act of 1977. The purpose of the Abandoned Mine Land Reclamation Act of 1977 was to establish a nationwide program to protect society and the environment from the harmful effects of mining operations by promoting environmentally conscious mining practices and the reclamation of abandoned mine lands, which were left without adequate reclamation prior to August 3, 1977 (Abandoned Mine Land Reclamation Act 1977). The Act required mining companies to reclaim mined areas to their natural condition (US Department of the Interior 2012) as well as provided minimum levels of protection concerning public health, safety and the environment. As part of this Act, the Office of Surface Mining, the federal regulatory agency that deals with abandoned mine land reclamation, was established. The Abandoned Mine Land Reclamation Act also established the Abandoned Mine Land Trust Fund to be used for the reclamation and restoration of areas affected by past mining. The fees are derived from reclamation fees on clean coal productions in both underground and surface mines (DEP 2015). Ultimately, this Act helped spread awareness of the need to promote and encourage technological advances and research in relation to the disposal of coal refuse (Vories 2000). As a result of the Act, many mine lands were reclaimed and restored to a more “natural” condition.

2.2 Abandoned Mine Lands in Pennsylvania

Pennsylvania constitutes approximately one third of total abandoned coal mine problems faced in the United States (Office of Resources Management 1983). Within the state, an estimated 133,000 acres of mine lands pre-dating the Mine Land Reclamation Act of 1977 (AMLRA) remain inadequately stabilized and could benefit from regrading and revegetation

(Toffey 2015). The problem of abandoned mine lands is so immense that it is estimated that approximately 1.4 million Pennsylvanians live within a mile of an abandoned site, and at least 44 of the 67 counties in the state are affected by these sites (Pennsylvania Campaign on Abandoned Mine Land 2015).

The abandonment of mine sites not only impacts the surrounding land, but also impacts watershed health. To this day, over 5,000 miles of Pennsylvania's 83,000 miles of streams have been polluted by acid mine drainage (AMD), which originates from abandoned mine sites and causes degradation of water resources. The discharge of AMD from mine sites affects the health of both terrestrial and aquatic ecosystems (Eastern PA Coalition for Abandoned Mine Reclamation 2015). Many mine areas have been reclaimed; however, many more remain untouched and reclamation of these lands needs to be addressed.

3.0 Study Area:

Located in the heart of the Central Appalachian Mountain region in Columbia and Schuylkill Counties, Centralia and the surrounding areas have experienced significant land use changes as a result of coal mining (Figure 1). Centralia is located in the Western Middle Coal Field (Stracher et al. 2006) of Pennsylvania. Centralia and the surrounding areas is underlain by the Pottsville and Lewellen formations, which are home to several major Anthracite coal seams, some of which include

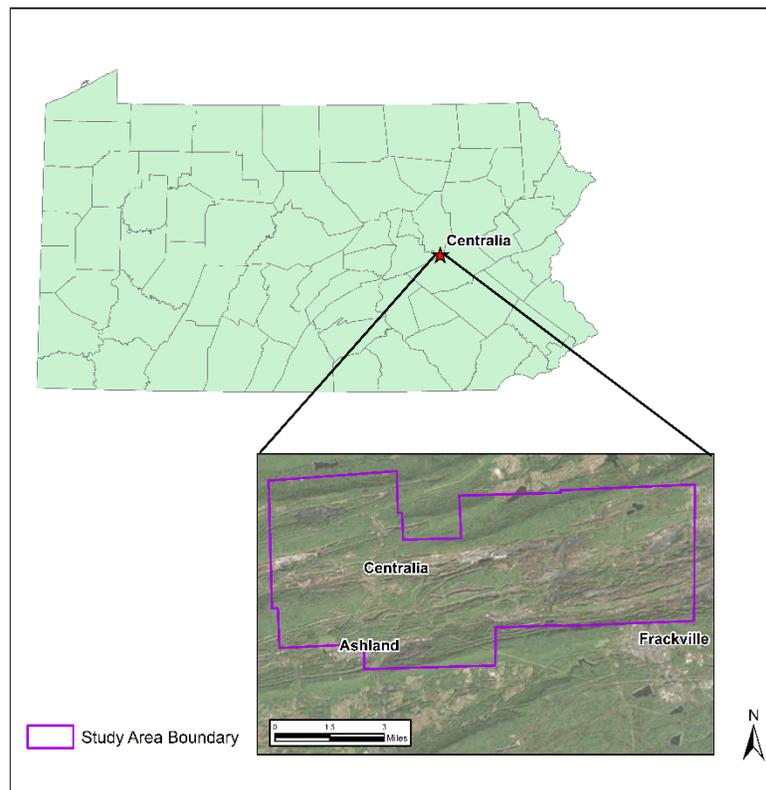


Figure 1. Study Area Map of Centralia and the surrounding area (Source: PennDOT 2015; ESRI 2015).

the Buck Mountain, Mammoth, Seven Foot, Diamond, Primrose, and Lewellen coals (FCOPG 2015).

Centralia's large scale coal mining began in 1842. This was not long after the completion of the Mine Run Railroad, the first railroad to connect the town to the surrounding areas (DEP 2015B). Over time, the industry began to slowly decline. Many coal mines were abandoned and left to return to forested land, or were converted to other uses, such as landfills or other industrial and commercial uses. In 1962, this abandonment increased as a result of the start of the Centralia mine fire. The mine fire began when local municipal workers, who were burning refuse in the local dump, accidentally ignited the Buck Mountain coal seam and started one of the longest burning coal fires in history (Aurand et al. 2015). As a result of the still-burning coal fire, Centralia is now nearly a ghost town and very little reclamation has occurred in the area. Evidence of the fire and the past mining operation can still be seen in the surrounding landscape as well as some location of active mines continuing to mine the Buck Mountain coal seam to the west (FCOPG 2015).

4.0 Data and Methods:

Datasets used in the analysis include the 1984 and 2006 Chesapeake Bay Land Cover Datasets (CBLCD) (Irani and Clagget 1984 and 2006), and historic aerial photographs from 1939 (Farm Service Agency 1939). The CBLCD is composed of 16 different land cover classifications. Land cover classes in the CBLCD are shown in Table 1. In order to simplify the urban and agricultural land cover classifications, low, medium, and high intensity development were combined into “urban” land cover class. Similarly, pasture/hay and cultivated crop were combined as “agricultural” land cover class. Mine lands fall within the barren land cover class.

This study utilized geographic information systems (GIS) to georeference historic aerial photographs gathered

Table 1. Land Cover Classes in the Chesapeake Bay Watershed Land Cover Dataset (Irani and Clagget, 2006)

Land Cover Classes in the CBLCD
Open water
Developed open space
Low intensity urban
Medium intensity urban
High intensity urban
Barren
Unconsolidated shore
Deciduous forest
Evergreen forest
Mixed forest
Shrub/scrub
Grassland/herbaceous
Pasture/hay
Cultivated crop
Woody wetland
Emergent wetland

from PennPilot, dated 1937-1942 (Farm Service Agency 1939) in the Centralia area using ESRI's current aerial imagery (2015). Historic aerial photographs covering Centralia and the surrounding area were georeferenced. Surface mines and tailing piles were digitized on of the georeferenced historic aerials. Areas (in hectares) for these delineated mine lands were determined and used to calculate land cover change.

Both the 1984 and 2006 Chesapeake Bay Land Cover Datasets (CBLCD) were clipped to Schuylkill and Columbia counties and were converted from a raster to a vector format. Both the 1984 and 2006 CBLCD vector layers were then clipped to the delineated mine land polygons and were dissolved according to land cover type. Areas and percentages of each land cover type within the mine land polygons were then calculated for 1984 and 2006. Changes in land cover within the abandoned mine land polygons between 1984 and 2006 were also determined.

Total land cover within the study area in both 1984 and 2006 was also examined by clipping the land cover data to the study area and then dissolving the layer based on land cover type. Changes in total land cover were calculated from 1984 to 2006. The total amount of mine land was compared for each time step (1937 compared to 1984, 1984 to 2006) as well as from 1937 to 2006 to understand the overall trends in mine land abandonment for the entire study area.

5.0 Results and Discussion:

Historic aerial photography showed significant amounts of disturbed mine areas throughout the Centralia area. Mining was so intense in the 1930s that some mining areas in the study area were even found encroaching upon people's homes within high density urban areas. In 1937, a total of 1,918.68 hectares, or 27% of the study area was made up of mined land. In 1984, this cover decreased and approximately 562.58 hectares of mine land were present in the study area. Between 1937 and 1984, approximately 1,356 acres of mine land were converted to other land cover types. This resulted in a 70% decrease in disturbed mine lands from 1937 to 1984.

In 2006, approximately 607.19 hectares of mine land were present in the study area. From 1984 to 2006, the amount of mine lands increased slightly from approximately 562 to 607 hectares. For the total time period analyzed (1937 to 2006), approximately 1,311 acres of mine land were converted to other land cover types. This showed an overall decrease in disturbed mine lands cover of about 68%. When examining the Department of Environmental Protection's existing reclaimed mine database, it was found that approximately 75 hectares of the 1937 abandoned mine lands have been reclaimed. This indicates that only approximately 4% of the original 1937 abandoned mine lands have been reclaimed or have been considered for reclamation (PADEP 2015).

Examining land cover in 1984 within the 1937 abandoned mine lands, trends in land cover change are evident. The total amount of each land cover type in 1984 within the 1937 abandoned mine lands is shown in Figure

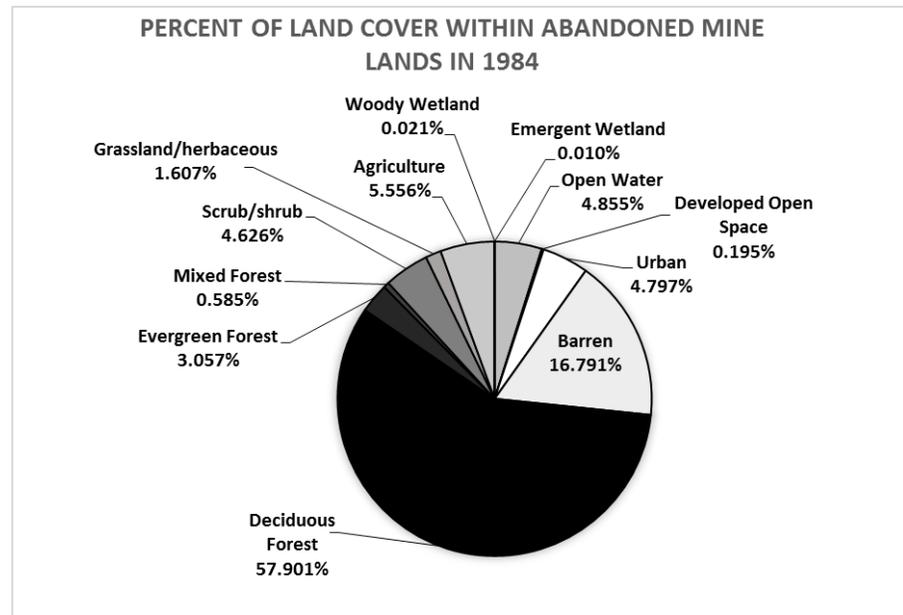


Figure 2. Percent of Land Cover within Abandoned Mine Lands in 1984.

2. Figure 3 is a map showing land cover

within abandoned mine lands in 1984. Approximately 83% of the abandoned mine lands have transitioned to other land cover types, whereas approximately 17% of abandoned mine lands have remained barren. In 1984, the dominant land cover type within previously abandoned mine lands was deciduous forest cover, which comprised 58% of these areas. Smaller amounts of mine land have transitioned to agricultural land (6%), scrub/shrub (5%) and open water (5%).

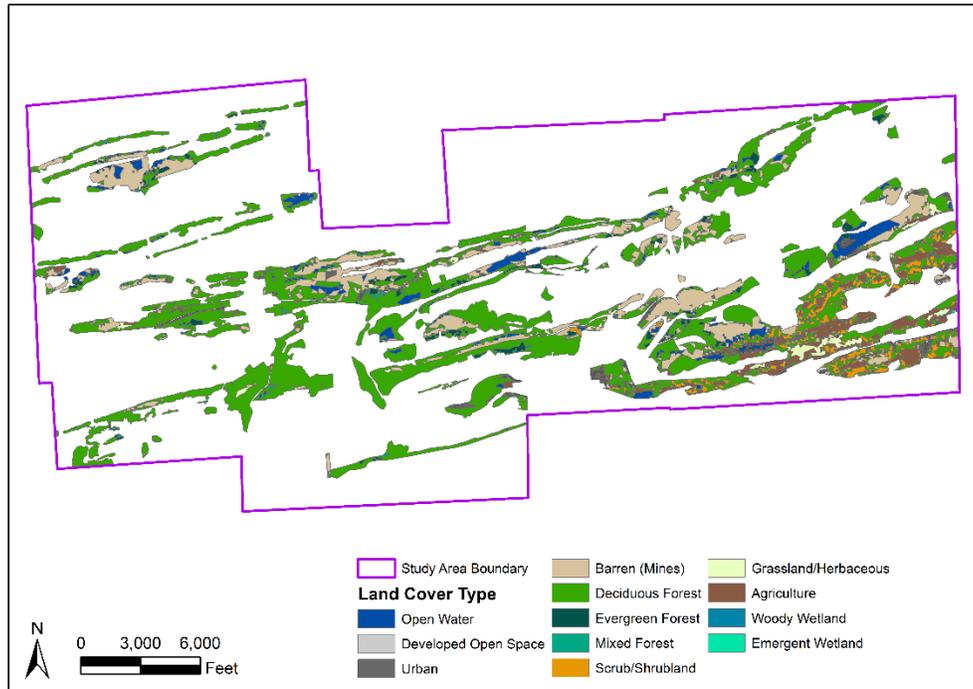


Figure 3. Land Cover in 1984 within Abandoned Mine Land Polygons (Source: Irani and Claggett 1984).

The total amount of each land cover type in 2006 within the 1937 abandoned mine lands is shown in Figure 4. Between 1937 and 2006, approximately 82 percent of the abandoned mine lands have transitioned to other land cover types and approximately 18 percent of the total land cover within abandoned mine lands has remained barren. Thus, from 1937 to 2006, the majority of the abandoned mine land areas have transitioned to other land cover

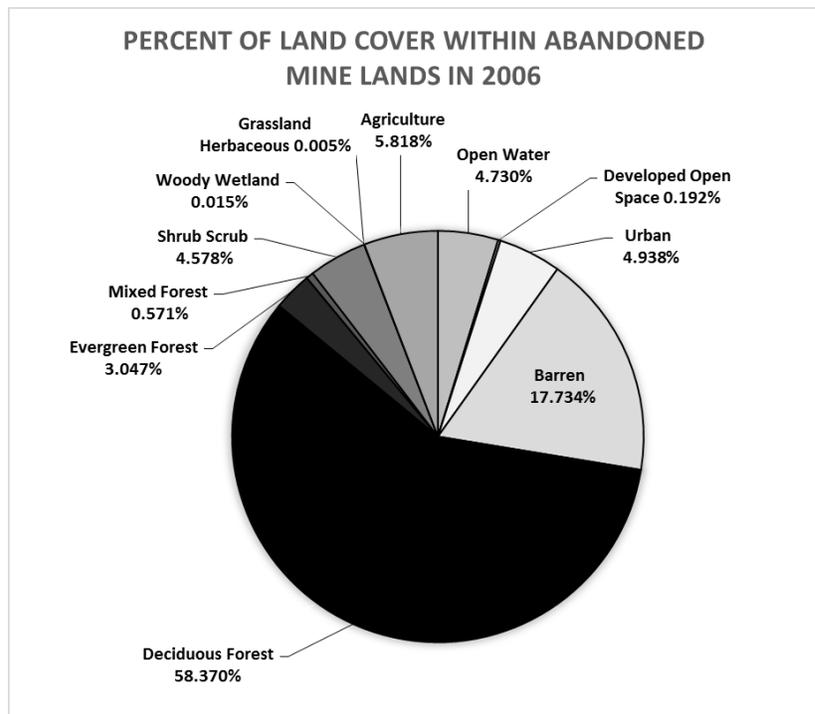


Figure 4. Percent of Land Cover within Abandoned Mine Lands in 2006

types. The majority of current land cover within the abandoned mine lands is deciduous forest at

58% of land cover and smaller percentages of abandoned mine lands have transitioned to agricultural (6%), scrub/shrub (5%), urban land (5%), and evergreen forest (3%). Barren land still remains the second most dominant land cover type, comprising 17.7% of the land area within the previously abandoned mine areas.

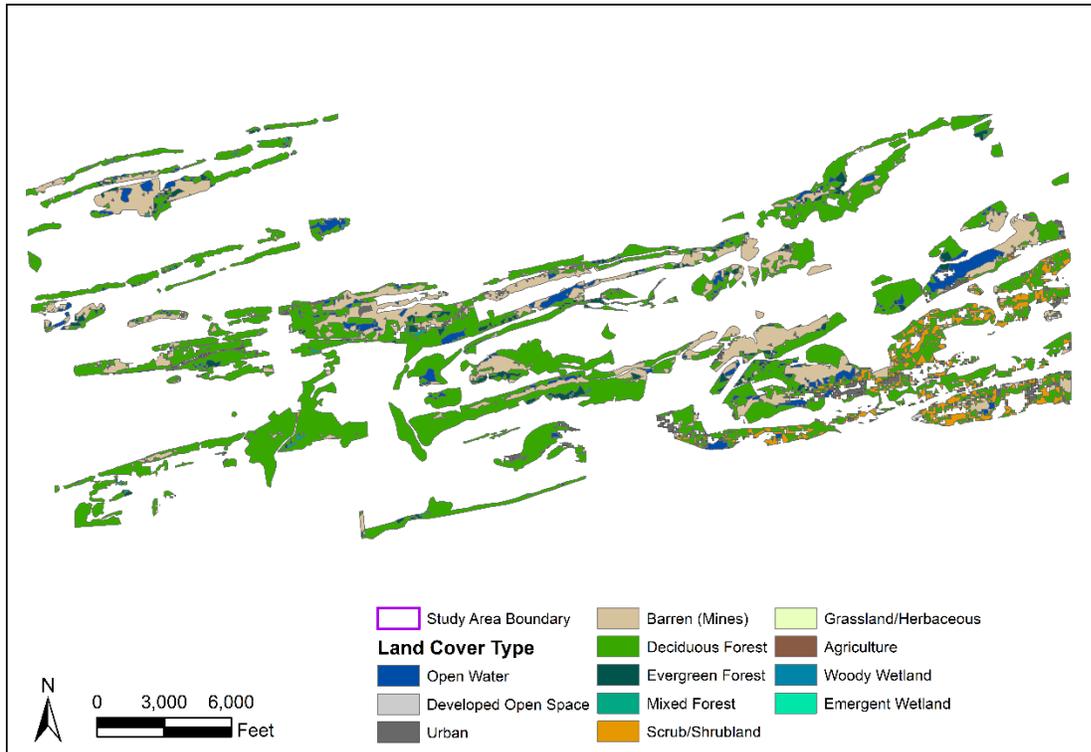


Figure 5. Land Cover in 2006 within Abandoned Mine Lands (Source: Irani and Clagget 2006).

In order to understand the dominant trends in land cover change throughout the entire study area, land cover within the entire study area was examined in both 1984 and 2006. Although land cover change from 1984 to 2006 was not substantial, some changes were noted. Figure 6 shows the differences in land cover from 1984 to 2006. Increases in cover of open water, urban land, barren land, evergreen forest, and agricultural land were observed for this twenty-two year period. The increases in urban land and barren land are consistent with the trends in land cover change within the abandoned mine lands.

From 1937 to 2006, previously abandoned mine lands still compose a significant portion of the land cover type, but the total amount of disturbed areas has been largely reduced and converted to a variety of other land types. Though barren land is only 17.7% of the land cover in

2006, it is still the second largest land cover type. The increase in barren land in the overall study area between 1984 and 2006 is likely active mines and are not of concern for reclamation efforts because they are subject to the AMLRA of 1977. This increase in mine land cover may reflect the increasing trends in Pennsylvania coal production during this time. Based on the historical trends in coal production within Pennsylvania, major mine land abandonment occurred in the Centralia area between 1937 and 1980. During this time, production of anthracite coal and in turn, mine cover was declining (PELSP 2011).

These data show that total abandoned mine land is slowly transitioning back to forested cover. Deciduous forest cover has increased substantially and became the dominant land cover in 1984 and 2006. Many studies have examined the rate of revegetation of abandoned mine sites. These studies have found that abandoned mine lands promote rapid succession of plant growth, with the re-establishment of grasses and other pioneer species in 10 years and hardwood forest within 40 years (Skousen et al. 1994). This may also explain the trends of decreasing grasslands and replacement of scrub shrub and forest in these areas in mine site between 1984 and 2006. Deciduous is the only type of forest growth that is increasing. This is likely a factor of the soil conditions on the site (Skousen et al. 1994). Although these mine sites are being rapidly replaced by vegetation through natural successional processes, the reclamation of these sites are still necessary to limit the risks of injuries and habitat loss resulting from collapse of mine workings.

5.1 Difficulties

There were several difficulties associated with the study and further work may need to be done to remove inaccuracies in the data. One difficulty was associated with the resolution of the land cover datasets used. The historic aerials allow for a finer data resolution than the Chesapeake Bay Land Cover Data series (CBLCD), which has a pixel size of 30 m by 30 m (Irani and Clagget 2006). Therefore, any patch of mined land is smaller than 30 m by 30 m was not accounted for in the CBLCD, but was accounted for in the digitized mine polygons generated from the historic aerials. This difference in resolution has a potential to skew the total amount of land cover change over time.

Another source of error is related to the georeferencing of historic aerial photographs. Due to the georeferencing process, there are inherent errors in the spatial reference of the historical aerial photography against the modern aerial photography. These errors can result from not placing the ground control points at the same exact location on each map. This issue has the potential to affect the accuracy of the exact positions of digitized mine land polygons. To limit the errors, historical aerial photographs were chosen based on resolution and date.

The land cover raster datasets were clipped to the digitized abandoned mine land polygons. As a result, excess land cover pixels were included in the abandoned mine land polygons. In order to resolve this issue, the land cover data was converted to a vector format. To accurately account for land cover data that were located on the edge of the abandoned mine lands, the land cover vectors were clipped to the abandoned mine land polygons. This introduces possible error, as the land cover data became slightly distorted when converted from raster to vectors, but resulting dataset was much more accurate than previous raster calculations.

6.0 Conclusion

Land cover in Centralia, Pennsylvania has been significantly altered as a result of coal mining activities. The abandonment of mine land results in various environmental problems, which affect both the environmental and the public health of the region. Some of these issues include acid mine drainage, subsidence as a result of mine collapse, coal fires, and landslides. Over time, abandoned mine lands may be converted to other land uses, such as forest land or utilized for commercial uses. The goal of this study was to quantify the types and amounts of land cover change within abandoned mine lands in the Centralia area. Understanding the land cover change over time in the Centralia region can help to understand trends in land cover change in abandoned mine lands. The result produced by this study can assist in an evaluation of the composition of the land cover in the anthracite fields of Pennsylvania. Future research related to the is study might consider the socio-economic effects of the trends in mine lands abandonment within the northeaster anthracite fields of Pennsylvania, an issue that was beyond the scope of this study.

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