# AN EVALUATION OF THE ECONOMIC AND ENVIRONMENTAL IMPACTS OF COAL MINING
# FLAT GAP, POUND, WISE COUNTY, VIRGINIA AS CASE STUDY

A THESIS PRESENTED TO
THE DEPARTMENT OF GEOLOGY AND GEOGRAPHY
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EVALUATING COAL MINING IMPACTS

An Evaluation of the Economic and Environmental Impacts of Coal Mining

Flat Gap, Pound, Wise County, Virginia as Case Study

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## Abstract

Coal mining has been and continues to be a large industry in southwestern Virginia, along the Appalachian Mountains, and more specifically in Wise County. Much controversy concerning the environmental impact of mining surrounds this industry. However, this industry also brings vast economic benefit to communities.

This research analyzes the Flat Gap mine site, an active mine site in which coal is being extracted today and in which no post-mine operation reclamation to the land has taken place, to determine if the economic benefit offsets change to the natural vegetative state of the land that occurs during the coal extraction process. More specifically, this research reveals an inverse relationship between the vegetative state of the land and the total amount of coal extracted from the land. This research also discloses that among the auger, surface, and underground methods of mining, the underground mining method distresses the natural vegetative state of the land most during the mining process.

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## List of Abbreviations

| | |
|---|---|
| AOC | Approximate Original Contour |
| CEDA | Coalfield Economic Development Authority |
| EIA | Energy Information Administration |
| DMLR | Division of Mined Land Reclamation |
| DMME | Department of Mines, Minerals, and Energy |
| NDVI | Normalized Difference Vegetation Index |
| SMCRA | Surface Mining Control and Reclamation Act |

# CHAPTER 1: INTRODUCTION

## BACKGROUND

Coal is defined as a solid combustible substance formed by the partial decomposition of vegetable matter. Coal is widely used as a natural fuel and provides more than half the electricity consumed by Americans (Merriam-Webster 2005; U.S. Department of Energy 2005). In fact, coal-fired electric generating plants make up the basis of America's central power system (U. S. Department of Energy 2005). Coal-generated power is among the cheapest energy sources available. While coal brings various benefits and uses to the world, the natural vegetative landscape of the earth is altered by the extraction of coal.

Coal is Virginia's most valuable mineral resource (Department of Mined Land Reclamation 2005). Virginia is the eighth leading producer of coal in the United States (Energy Information Agency 2003). The four primary uses of coal are electric production, industrial uses, coke, a fuel produced from coal, and residential and commercial uses (DMLR 2005). Table 1 lists a breakdown of the primary uses of coal in Virginia. Clearly, coal plays a vital role in Virginia's economy.

Table 1: Coal Usage in Virginia (DMLR 2005).

| Percentage | Usage |
|---|---|
| 62 | Electric production |
| 31 | Industrial uses |
| 6 | Coke |
| 1 | Residential & commercial |

Statistics from the Energy Information Administration (2003) indicate an annual percent change of –4.1% from 1990 to 1999 in the total amount of coal produced in Virginia. The number of mining employees has declined 6.9% during the same time period (EIA 2003). Although increased technology allows fewer men to do the work, a trend exists between the drop in production output and the number of mining employees in Virginia as listed and demonstrated in Table 2, Table 3, Figure 1, and Figure 2. As production decreases, the number of employees in the industry does also.

Table 2: Industry Specific Statistics of Virginia (EIA 2003).

| Category | 1990 | 1995 | 1996 | 1997 | 1998 | 1999 | % Change |
|---|---|---|---|---|---|---|---|
| Production Total | 46,917 | 34,099 | 35,590 | 35,837 | 33,747 | 32,294 | -4.10 |
| Employees | 10,342 | 6,919 | 6,241 | 6,235 | 5,887 | 5,450 | -6.90 |

Table 3: Coal Mining Trends of Lee and Wise Counties, Virginia (DMLR 2005).

| Year | Coal Production* | Mines | Employees | Wages** |
|---|---|---|---|---|
| 1993 | 15.7 | 111 | 3,036 | $85.2 |
| 1994 | 16.0 | 125 | 3,021 | $85.9 |
| 1995 | 15.0 | 116 | 2,886 | $83.0 |
| 1996 | 15.6 | 114 | 2,479 | $75.0 |
| 1997 | 16.3 | 120 | 2,793 | $77.0 |
| 1998 | 14.9 | 125 | 2,486 | $73.1 |
| 1999 | 14.7 | 126 | 2,458 | $66.8 |
| 2000 | 15.5 | 130 | 2,172 | $50.2 |
| 2001 | 14.5 | 126 | 2,284 | $79.7 |
| 2002 | 15.7 | 120 | 2,020 | $76.0 |
| 2003 | 14.4 | 117 | 1,959 | $75.2 |

*Million tons
**Million

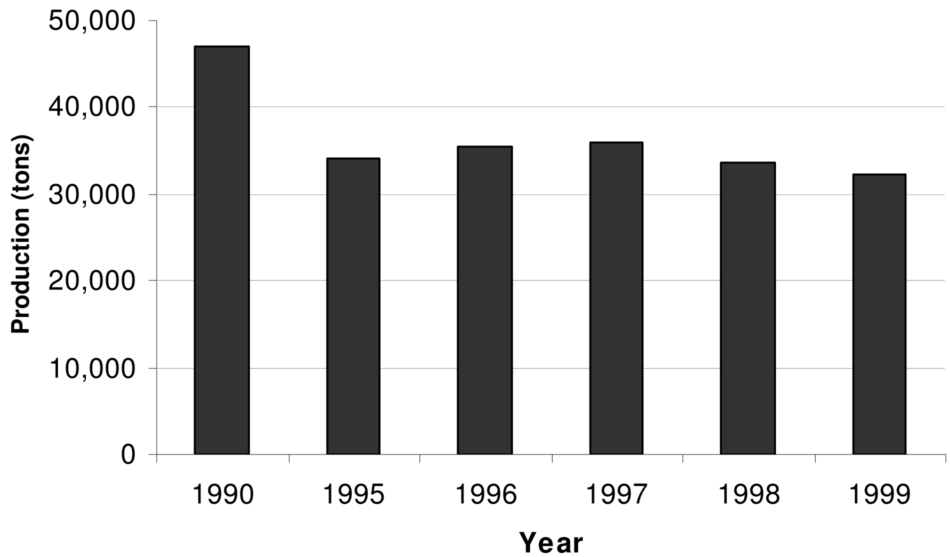


Figure 1: Virginia Coal Production 1990 –1999. Chart illustrates changes in Virginia's coal mining industry production from 1990 to 1999.

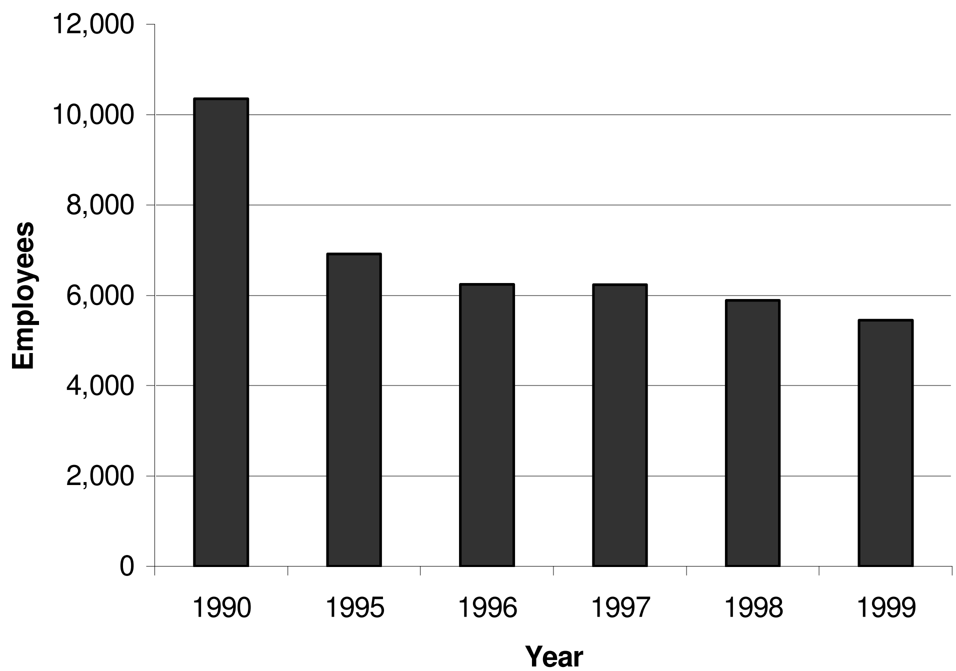


Figure 2: Virginia Coal Industry Employment 1990-1999. Chart illustrates change in Virginia's coal mining industry employment from 1990-1999.

The coal mining industry entered Wise County, Virginia in 1890 along with the building of the Louisville & Nashville and the Norfolk & Western Railroads (Kennedy 1928). Coal mining may cause environmental concerns; however, it has provided employment for multi-generations of Wise County, Virginia residents (Shackleford 2005). Since the late 1890's when coal mining first emerged in Wise County, it has taken responsibility for the economic prosperity of the county. However, from the beginning of the 1990's until recently, Wise County and the coal industry in general had been on a steady decline. Figure 3 and Figure 4 clearly show that the coal mining industry is not as lucrative as it once was. Both the number of coal mining establishments and employees has significantly dropped since the year 1978. This depression in the industry has resulted in less economic prosperity and more hardships for the residents of Wise County. For the past century, the county's workforce relied upon the coal mining industry as a means of employment for supporting a family; thus, many did not seek other options such as a college education. While these factors significantly impact the economic status of Wise County, its businesses, and its citizens, Figure 5 illustrates that the overall coal production in Wise County has not suffered, due to the factor that modern technology requires fewer workers and allows more coal to be extracted from the mining sites. Wise County has been and continues to be a large provider of coal in Virginia.

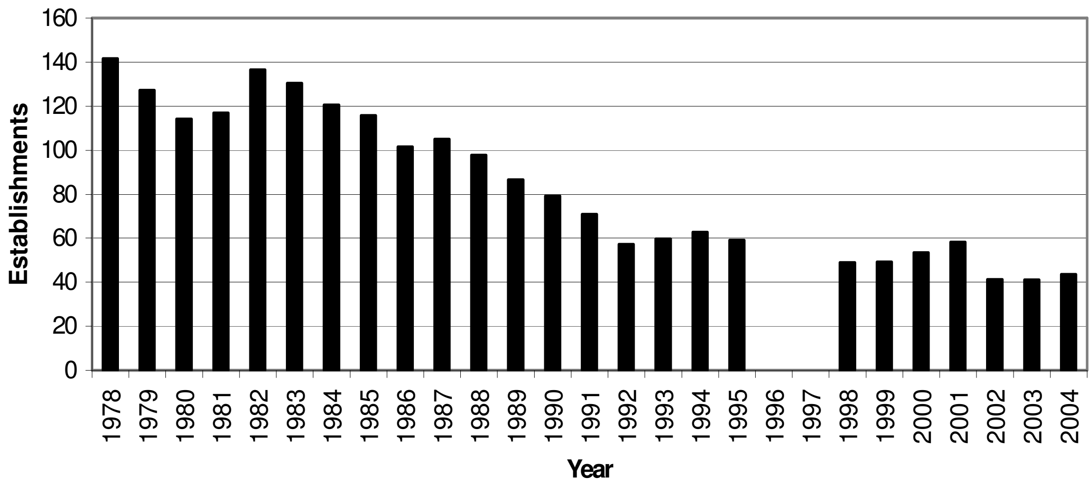


Figure 3: Mining Industry Establishments in Wise County, Virginia from 1978 thru 2004. Chart shows the average number of mining establishments located in Wise County, Virginia each year except 1996 and 1997 in which data was not disclosed.

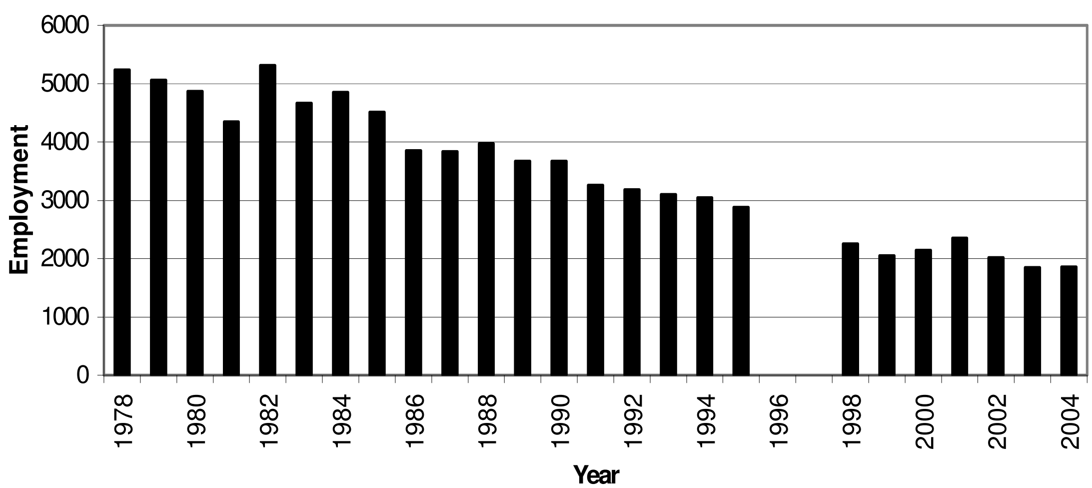


Figure 4: Mining Industry Employment in Wise County, Virginia from 1978 thru 2004. Chart shows the average number of individuals employed by the mining industry located in Wise County, Virginia each year except 1996 and 1997 in which data was not disclosed.

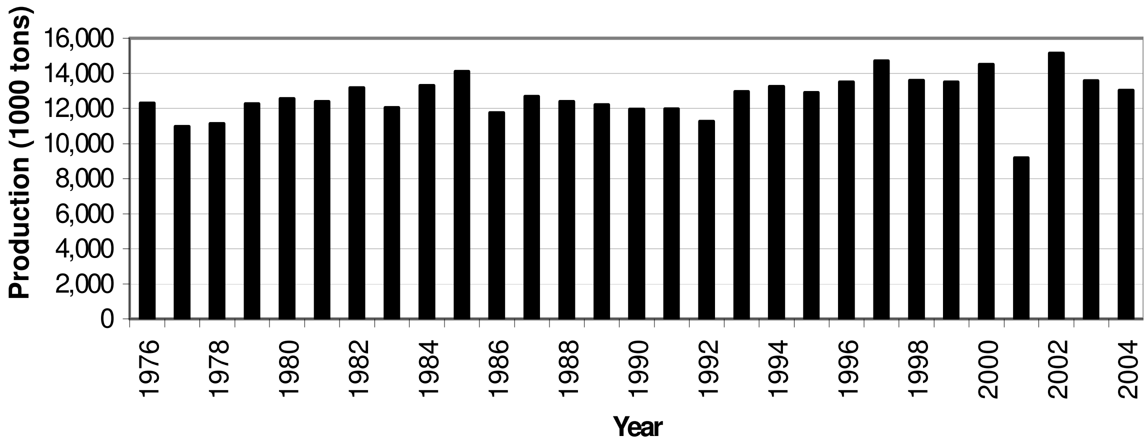


Figure 5: Historical Coal Production in Wise County, Virginia from 1976 thru 2004. Chart shows the tonnage of coal extracted by the mining industry located in Wise County, Virginia.

The coal mining industry provides much needed revenue to the local government treasury through the severance taxes assessed by the county. Code of Virginia statutes 58.1-3712 (2006a) and 3713 (2006b) authorize counties and cities to levy a two percent severance tax on coal. The revenue is divided into several funds as follows: one percent supplies the general fund, which funds the general operating expenses of the county, one quarter of one percent is used to create improved water and sewer infrastructure within the county, one-half of one percent is placed in the coal haul roads fund for the purpose of improving public roads within the county, and one quarter of one percent is provided to the Coalfield Economic Development Authority (CEDA) for the purpose of creating new jobs and economic diversification within the county. According to the 1998 annual report of the Virginia CEDA, over 1,000 new manufacturing and technological jobs have been created in Wise County since 1998 in addition to providing millions of dollars in grant funding to build technology parks, infrastructure, and buildings to further economic development. The coal severance tax rate is based upon the annual gross receipts from the sale of the coal extracted from the earth within the county's boundary. So, the amount of revenue collected annually is contingent upon the contract and spot market value of coal, which is determined by the demand curve. In times of energy crisis, coal is in higher demand; therefore the spot cost goes up. Figure 6 shows the annual revenue collected through these levies in Wise County, Virginia. Although the coal industry is not providing the county with as many jobs as in years past, the coal industry continues to supply the county government with much needed revenue through the severance taxes paid.

Coal is excavated from the earth through various mining methods. This research studies mining sites using surface, auger, and deep mining. According to the Department of Mined Land Reclamation (DMLR) (2005), surface mining is fulfilled by uncovering the soil over the coal seam and blasting the earth to remove the coal. Auger mining consists of boring into the coal seam at the base of the strata exposed by excavation. Deep mining consists of digging "rooms" under the earth allowing miners to go underground to retrieve the coal (DMLR 2005). These methods alter the land not only to mine the coal but also to build coal haul roads and conveyor systems to cleanse, load, and haul the coal, which is part of the reclamation process (Wooten 2005).

Tonnage may be defined as the amount of work that has been done in terms of mining. The comparison of tonnage and vegetation establishes the fact that vegetation is altered during the times the most work is done. This research explores the environmental impact of each of the aforementioned coal mining methods on the land by comparing the loss of vegetation throughout the mining site from 1976 to 2002. The research analyzes

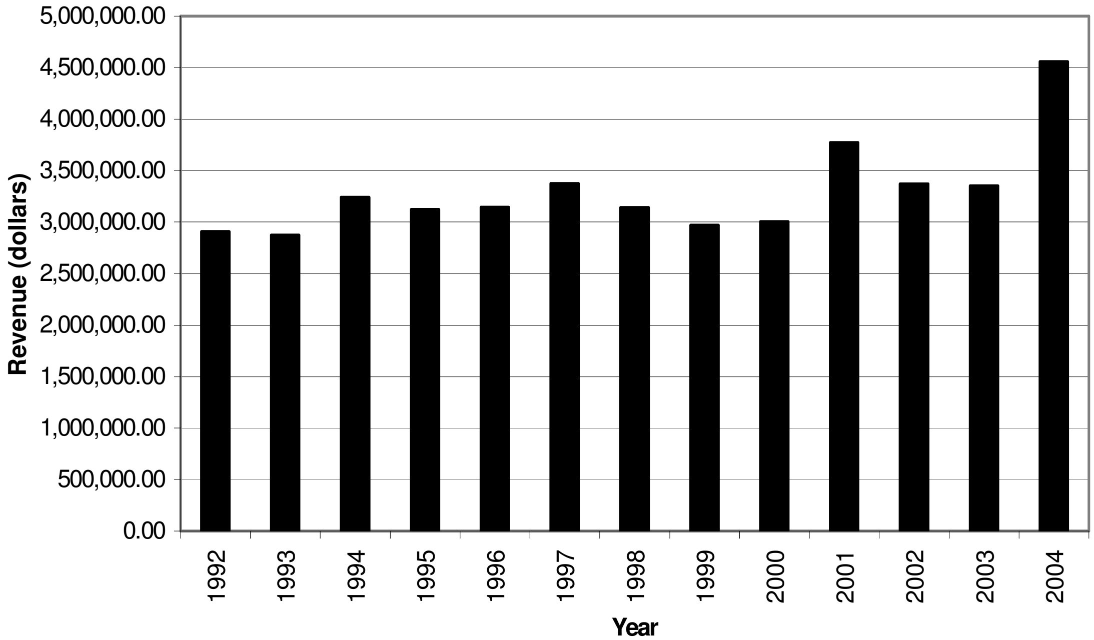


Figure 6: Wise County, Virginia's Coal Severance Tax Revenue Collection, 1992-2004. Chart shows the dollar amount of revenue collected each year from 1992 through 2004 from the mining industry.

the study site as a whole and each mining method individually to determine which alters the vegetation most.

Deputy Secretary of the United States Department of the Interior Steve Griles stated that if you run a mining company, you also run an environmental and reclamation company (Igo 2005). Reclamation is a vital part of the coal industry. Wooten (2005) states that "reclamation begins before any soil is removed from the site." Sound reclamation plans are put in place well before mining begins not only to meet state and federal regulations but also to prevent unnecessary alterations to the natural landscape. Nevertheless, coal mining and associated activities inevitably interrupt the current natural state of forests, water resources, and minerals (Buckley 1998). In order to limit the amount of overall change in topography, President Jimmy Carter signed the Surface

Mining and Control Reclamation Act of 1978, SMCRA, which requires the mining industry to return the land back to the approximate original contour, AOC. However, there are exceptions to this act. A post-mine land-use type may differ from the original land-use type. For example, pastureland is especially important to the southwestern Virginia region due to the lack of level farmable land (Shackleford 2005). A coal company must provide proof of post-mine land-use type in the form of contracts in order to reclaim a site to any land-use type other than the original (Wooten 2005). In fact, before a permit may be issued to begin mining, all proper paperwork must be submitted and a monetary bond is established for the sole purpose of reclaiming the land to the agreed upon post-mine-land-use type (Kessner 2005). The DMLR will not release the bond until proper reclamation is ensured, which may take up to five years (Shackleford 2005, Wooten 2005). If a company fails to reclaim, the bond is forfeited and used to reclaim the site by state contract (Kessner 2005).

While the coal mining industry is not the sole industry altering the land, coal extraction is constantly scrutinized. Protecting the environment is such a priority that protestors stand and march in opposition to the devastating effects of the mining industry (Tate 2005). Protestors speak negatively about mining while ignoring the economic benefits enjoyed due to the industry. Just recently, Virginia's Former Governor Mark R. Warner acknowledged that due to the rising fuel costs across the nation, more people are turning to alternative sources of energy such as coal (Warner 2005). With this latest change in the coal economy, spot market coal prices have spiked in comparison to recent years. This increased demand for coal may mean sacrificing undisturbed land but also means an increase in energy production, gainful employment, and government revenue.

**RESEARCH OBJECTIVES**

This research is a necessary response to the explicit concern surrounding the environmental and economical effects of coal mining. The research objectives are to illustrate that the vegetation is altered when coal is extracted from the land, to provide evidence that an inverse relationship exists between the vegetative state of the land and the total amount of coal extracted from the land, to determine which mining method causes the most change in vegetation, and to show that the coal mining industry supplies revenue through the taxes paid on extracted coal. Ideally, any rural area that forgoes vegetative landscape will reap economic benefits the coal mining industry has to offer such as gainful employment, increased governmental revenue, and so forth.

## CHAPTER 2: LITERATURE REVIEW

Literature depicting the development of ideas and problems relating to the coal mining industry, remote sensing, normalized difference vegetation indices, and change detection of agricultural and vegetated areas are reviewed and evaluated to define the rationale of this research. Various research methods are compared to determine which method best serves this research.

### COAL MINING INDUSTRY

The coal mining industry has been scrutinized since its origin due to the distress it places upon the land. However, the realization that without the industry many rural communities would become deserted ghost towns must be weighed against the environmental impact. Strong importance must be placed on the fact that despite the negative environmental impacts, the coal mining industry supports many rural communities.

The coal mining industry affects both the economical and environmental aspects of a community. Since neither has precedence over the other, both aspects are researched to indicate how the coal mining industry affects a community.

Many rural towns came into existence as coal camps, and mining was the only means of livelihood to the area. The loss of a coal mining operation causes devastation to any area dependent upon the coal mining industry. Jeff Lester (2004a) describes one rural area coping with the loss of the Westmoreland Coal Company. In 1995, the once lucrative Westmoreland Coal Company closed all Virginia operations, leaving many rural areas in a state of shock and concern as they were left without jobs, and thus, income. During the ten-year time frame of 1993 to 2003, over 2,500 Virginian's associated with the United Mine Workers of America program lost their jobs (Lester 2004a). Over 1,000 of the individuals were from southwest Virginia (DMLR 2005). Rural areas, such as the counties of southwestern Virginia, were especially economically disrupted by the mine closure (Lester 2004a). Loss of employment not only affects individual families but it also hinders the economic development of the community as a whole due to the decrease in consumer spending.

Hazelton, Pennsylvania is yet another rural town negatively affected by the loss of the coal mining industry. Dan Gilgoff (2002) describes the devastation the residents of Hazelton have endured for nearly half a century. In fact, the town's population has dwindled by half since 1940. Although the local economic development corporation's president, W. Kevin O'Donnell, has hope and a plan for the abandoned strip-mined land, many residents have lost their sense of community pride. Even though other business has begun to move back into the community, there is no sense of town pride as before. The residents no longer feel the security of steady income and stable employment. Rather, individuals capable of building equipment from scratch now simply load furniture into trucks. The residents of the community deeply depended upon the coal mining industry, but now that it is gone, little hope prevails that the town will ever be what it once was (Gilgoff 2002).

In such circumstances, atypical forms of development may be necessary to help restore a community. Jeff Lester (2004b) describes how three Pennsylvania communities coped with life after coal mining. Jim Thorpe, Pennsylvania, formerly known as Mauch Chunk which consisted of a high Native American population, became the epicenter of coal mining in the 1820s. However, after the Great Depression of 1929, Mauch Chunk lost the coal mining industry to competition from western Pennsylvania coal producers. With no form of development coming into the community, officials accepted a tourism opportunity. Jim Thorpe was a legendary Native American athlete. Upon his passing, his home state of Oklahoma failed to erect a suitable monument in his honor. The town of Mauch Chunk agreed to honor Jim Thorpe by changing the town's name and making the town the final resting place of Jim Thorpe. Today Jim Thorpe, Pennsylvania accepts tourists who can tour a restored historical district which includes the office building of the first major coal company, Lehigh Coal and Navigation Company, ride a switchback train used to transport coal from the mines to the canal, and much more (Lester 2004b).

Eckley, Pennsylvania also restored the historical significance of the community after coal mining. Eckley was created as a coal-mining town in 1854 and housed 1,500 miners. Now the town is home to only a few families. However, Eckley was the main setting for the film "The Molly Maguires" starring Sean Connery. A large portion of the town was restored to resemble its 19th century roots (Lester 2004b). Although mining is not a dominant industry in these Pennsylvania communities, the use of tourism and history allows the communities to maintain their heritage and a stable standard of living.

A similar situation can be seen in the Mount Everest region of Nepal, which is a site of abundant tourism. Past studies of the region have implied a drastic change in landscape over the past fifty years. Stevens (2003) found the past studies to be misleading. Tourism has contributed to the thinning of the forest but there has been little deforestation overall. Understanding and evaluating the environmental history of the region shaped Stevens' theory. Comparison of past visitors' accounts and photos with current region trends led Stevens to believe that little deforestation has occurred throughout the region since 1950. Furthermore, tourism has brought major economic changes to the region. The Sherpas who are native to the region prosper due to the tourism (Stevens 2003). There are negative associations with tourism including pollution, litter, and increased pressure on the natural environment, but overall little change has taken place to the environment while much change has occurred to the economy. The same may be said about the coal mining industry.

Although the mining industry has been a leading employer in many states throughout the nation, local trends suggest that coal-mining employment is steadily declining even though production is not, as illustrated in Figures 3, 4, and 5. Researchers have found that no relationship exists between coal production and coal industry employment (Bockosh et al. 2002). During the last two decades United States coal production increased by forty percent while employment decreased by fifty-six percent (Bockosh et al. 2002). These changes occurred through a "moderate and constant" adaptation (Bockosh et al. 2002). Data collected from the County of Wise mimics the results of Bockosh. From 1978 to 2002 Wise County's coal production increased by thirty-six percent while coal industry employment decreased by sixty-one percent. One factor relevant to this trend is technology (Bockosh et al. 2002). Due to the increase in technology, machines now do the work of multiple laborers. Another factor related to the decline of coal industry employment is the use of independent contractors in mining (Bockosh et al. 2002). While statistics indicate less employment in mining, a steady increase is found throughout other industries such as privately held business and the commercial sector industry (Bockosh et al. 2002).

Although the mining industry may impart a positive affect upon the economy, substantial changes occur to the environment. Homer Aschmann identified four stages of the development of a mine. The first stage is prospecting and exploration; the second stage, investment and development; the third stage, stable operation; and the fourth stage, alteration of the forest of the mining region (Sluyter 1998). Normally minerals such as coal are found among forested lands. In order to collect the coal alteration to the land is necessary. Historically, coal-mine operations removed all timber before mining commenced (Buckley 1998). The timber was substantially used for railroad cross ties and mining props (Buckley 1998).

A US Newswire (2003) release by federal and state agencies addresses the environmental and economic impacts of coal mining on the regional economy. The release particularly addresses the effective protection for human health and the environment. The study area for the release consists of approximately 12 million acres of land in Kentucky, southern West Virginia, western Virginia and areas of east Tennessee. Federal and state agencies are concerned with the environmental impacts the coal mining industry has upon the Appalachian streams. To counteract these negative impacts, an environmental impact statement was released in 2003 recommending greater protection for the Appalachian streams. The Appalachian coal industry affects eastern Kentucky, southern West Virginia, western Virginia and areas of east Tennessee. The United States Department of Energy estimates that 28.5 billion tons of coal exist in the study area. This coal provides energy to the nation. Coal is an important economic component of this region, bringing jobs and tax revenue.

The environmental impact statement seeks to enforce stricter regulations in the following areas: stream protection, stream restoration, advanced watershed planning, revision of the Clean Water Act, clarification of Surface Mining Control and Reclamation Act, adherence to reclamation Best Management Practices, promotion of reforestation, reduction of mining flood risks, revision of the Clean Air Act, and preparation of protection plans for endangered species. The Army Corps of Engineers, Environmental Protection Agency, Fish and Wildlife Service, Office of Surface Mining and Department of Environmental Protection are involved in the creation of the environmental impact statement (U.S. Newswire 2003).

This US Newswire (2003) report reinforces the fact that regulations are in effect and must be adhered to by the mining industry. The mining industry strives not only to meet, but also to exceed set regulations. In most cases, reclaimed mining land is more suitable for development than pre-mining land because less land work is required of the developers and/or local government to prepare the land for development.

## REMOTE SENSING OF VEGETATION

Remote sensing is a tool that may be used to help monitor the vegetative status of an area. Through the use of remote sensing it is possible to calculate vegetative change over time. There are numerous methods to determine change through remote sensing. Reviewed literature analyzes various methods to determine if a previous study's method may meet the requirements of the research at hand.

Satellite remote sensing is the preferred technique for monitoring vegetation (Quijano 2003). A primary application of remote sensing is to identify patterns of vegetation disturbance and to assess changes in vegetation over time (Bean 2000). An abundance of remote sensing sources exist for the comparison of vegetation over time.

For years, aerial photography has been used in the forest inventory process but not without problems. Interpreting aerial photography is time consuming. Optical remote sensing systems also have many limitations such as acquiring data due to cloud cover and the extent of canopy penetration (Bourdeau and Dechambre 1999, Wallington et al. 2003). Another method of forest inventory uses a nadir-looking ranging scatterometer. The nadir configuration provides vertical profiles of the vegetation. This is a way to show tree patterns in a forest (Bourdeau and Dechambre 1999).

Shoshany's research (2000) exemplifies various methods to detect change in vegetation using various forms of remotely sensed imagery. The Landsat Thematic Mapper (TM), the Landsat Multi-Spectral Sensor (MSS), Satellite Pour l'Observation de la Terre (SPOT), and the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) are the main data sources for vegetation monitoring (Shoshany 2000). More specifically, the TM bands 3, 4, 5, and 7 are most suitable for biomass analysis (Shoshany 2000). The multi-spectral classification of TM images with 30-meter resolution differentiated among forest, woodland, chaparral, grassland, and low-density vegetation types (Nelson, et al. 2000).

Gupta (1998) used Landsat TM imagery to classify land use and land use changes over the Jharia coalfield of India. The study implemented the false color display and the normalized difference vegetation index (NDVI) to study the vegetation of the study area. Change was detected through image differencing, image ratios, and NDVI differencing (Gupta 1998). The NDVI derived from multi-resolution pixels of Landsat data has proved to be an effective indicator of vegetation fraction (Quijano 2003). Typically, areas with a low NDVI value of .1 or less represent lands covered by rock, sand, or snow. Moderate NDVI values of .2 to .3 indicate shrubbery and grasslands. High NDVI values of .6 to .8 are representative of tropical rainforests (Weier and Herring 2001). Studies reveal that NDVI is the more widely used vegetation index model (Bean 2000). Landsat MSS data is designed to distinguish green vegetation from soil and reduces topographic and atmospheric effects (Bean 2000). Atmospheric conditions have caused false results in other studies (Song and Woodcock 2003).

In scientific analysis it is often necessary to convert real variables into a Boolean variable. Pontius and Batchu (2003) examined land cover change in India using remote sensing. They used raster imagery to determine forest disturbance. For the purposes of the study, the numerical indicator 0 was equivalent to a period of time before human intervention, numerical indicator 1 represented the year 1920 and numerical indicator 2 represented the year 1990. A resolution of 1 kilometer by 1 kilometer was used. At time 0 a fully forested landscape was assumed. As humans began to interfere with the natural state of the land, land cover changed. At time 1 and time 2, less vegetation existed than at time 0 (Pontius and Batchu 2003).

There are many ways land changes may be tracked and documented. Along the nation's western region monitoring and tracking land changes has become of utmost importance because landowners are sharing their rangelands with others. It is important to maintain the land and ensure the land is not overused. The Bureau of Land Management holds the duty of reporting to Congress the changes in the land. The Bureau of Land Management enlisted the help of Pacific Northwest National Laboratory in

Richland, Washington to develop a way using remote sensing to monitor the land. Specifically, Pacific Northwest National Laboratory was to be cost-efficient and simple in the design and explanation of the program (USA Today 2003).

Pacific Northwest National Laboratory used aerial photography and digital satellite images to depict and track changes in the vegetative states of the rangelands. Areas of bare soil were especially of interest due to the overuse of the land. The researchers considered the use of Landsat imagery due to speed and ability to capture 8,000,000 acres of land in a single photo; the Bureau is responsible for the management of 262,000,000 acres. But, it is much harder to depict small changes in the land in such a large acreage due to the diversity of the lands. The solution to this problem was to subdivide the land into similar areas according to soil type, vegetation and slope. Identifying anomalies in a homogenous setting proved to be much simpler and faster (USA Today 2003).

Adapting a simple methodical way of identifying the anomalies was important to the success of the project. According to Larry Cadwell, "Each pixel of a remote sensing image gives a spectral signature for that area on the ground, and when you have a change in vegetation cover resulting from some disturbance, that change is reflected in the spectral signature" (USA Today 2003). The spectral signature associated with each pixel of land in a similar subdivided group will be similar until a change occurs within the group. That change in spectral signature indicates overgrazing, fire or weed invasion. One element not discussed in the article is the temporal error. Imagery taken during cold winter months will indicate more barren lands while warm summer months indicate vegetated land. Temporal factors must be taken into consideration when studying the spectral signature so that snow-covered land is not mistaken for overgrazed land (USA Today 2003).

The final product launched by the Pacific Northwest National Laboratory allowed the Bureau of Land Management and landowner to view and pinpoint locations on a web-based mapping system.  Over time, trends in vegetative states will occur and users will be able to follow them using the system.

# CHAPTER 3: CONCEPTUAL FRAMEWORK AND METHODOLOGY

## STUDY AREA

Wise County, Virginia is a rural community with a population of 40,123 (U. S. Census Bureau 2000). Wise County was established on February 16, 1856 at which time no industry existed. Early settlers were aware of the existence of coal but had no meaningful outlook as to the true value of coal. Men from the coalfields of Pennsylvania began settling in Wise County and commenced the mining industry in 1890 (Kennedy 1928). Still today, mining is a significant economic driver in the county.

Six localities and one city lie within the boundaries of Wise County. This research focuses on one specific mining site known as the Flat Gap mine site located in the town of Pound in Wise County, Virginia. The mine site is located in the western portion of the county and is approximately four miles from the nearest town corporation limit.

The study area site consists of twelve active mine sites encompassing approximately 10,796 acres of land. Coal production in this area is achieved through auger, deep, and surface mining methods. Each active mine site is granted a permit number upon successful completion of the DMLR permitting process. Portions of this study area received permits for mining in early 1983, others as recent as June 2001. Since production began, this study area has produced 47,970,000 tons of coal. Although the industry does estimate available tonnage, there are no estimates regarding the total amount of coal to be produced by this site (Kessner 2005). Refer to Figure 7 for a more complete description of the site.

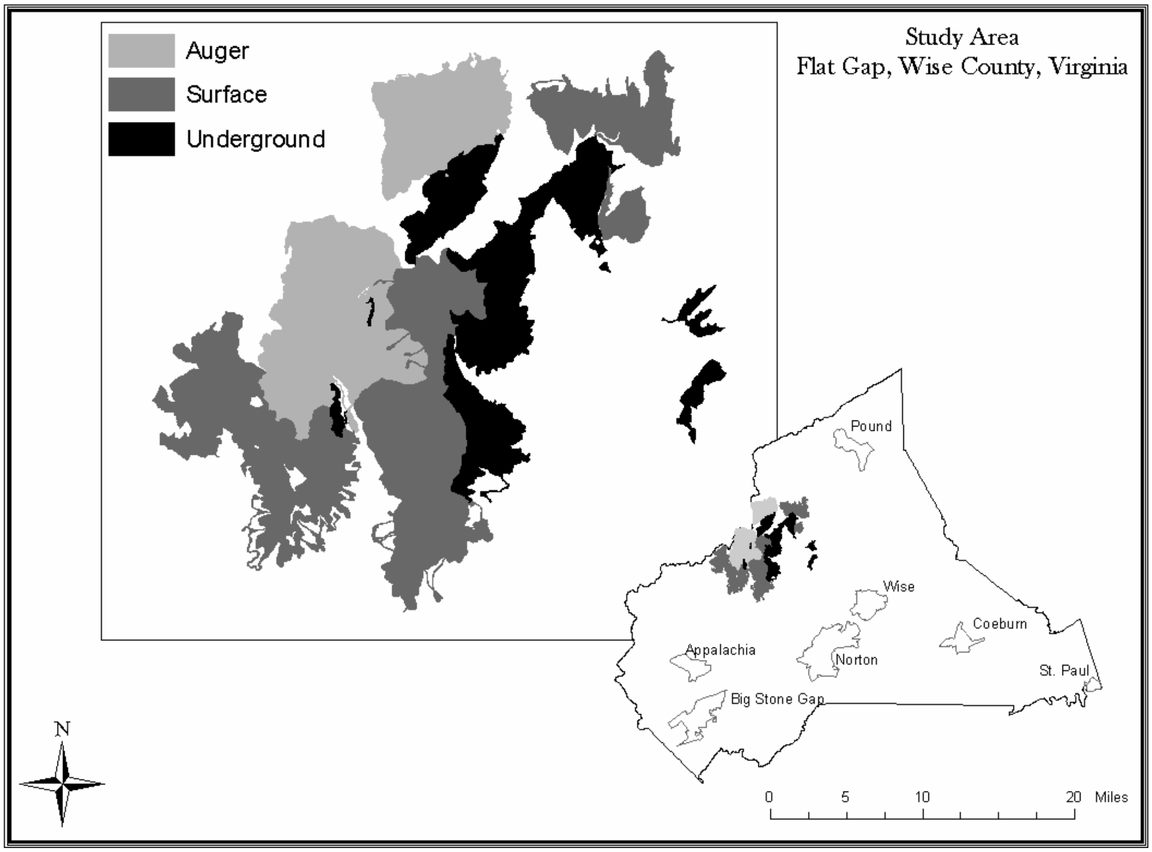


Figure 7: Map of study area. County boundary, town corporation limits, and the Flat Gap mining site are depicted.

**DATA SOURCES**

In order to analyze the change in vegetation over the study area, specific data was acquired. The use of imagery collected by the Landsat satellite was downloaded from the Global Land Cover Facility of the University of Maryland. Bands one through four of the available Landsat imagery covering the study area were downloaded for August 1976, June 1987, September 1990, September 1999, and May 2002. The 1976 image is derived from the MultiSpectral Scanner, the 1987 and 1990 images are derived from the Thematic Mapper, and the 1999 and 2002 images are derived from the Enhanced Thematic Mapper Plus (ETM+).

Digitally mapped shapefiles of the study area were gathered from the Department of Mines, Minerals, and Energy's Department of Mined Land Reclamation (DMLR). The DMLR creates and maintains digital files of the mining sites within Wise County. For the purposes of this research attribute data consisted of the permit number, permit issuance date, site description, site size, and mining method. The permit number is a unique identifier assigned to each mining site. If questions arose during the research process, the permit number allowed for easy retrieval of additional data from the DMLR. The permit issuance date declares the exact date a mine site is permitted to commence mining. No mining activity is permitted on the site until the permit is issued. The site description attribute provides a general geographic location of the mine site. The area of the mine site is given in acres. The attribute data also expresses the mining method used for each mine site.

Various datasets were collected in order to establish a relationship between employment and production. The EIA provides coal production and industry specific employment data for the state of Virginia for the years 1990 through 1999. The DMME provides industry specific data on the county level. The DMME provides coal mining trend and establishment data. They also provide in collaboration with Virginia Tech coal production data for the years 1976 through 2004. The Virginia Employment Commission supplies the Wise County Mining Employment dataset. The dataset includes employment data from 1978 to 2002 excluding the years 1996 and 1997. Although the dataset is incomplete, the years 1987, 1990, 1999, and 2002 are compared to establish a relationship between vegetation and employment in Wise County, Virginia. The governing body of Wise County provides the coal severance tax legacy dataset. All the datasets are necessary to the research methodology.

**RESEARCH METHODOLOGY**

The aforementioned data was gathered to provide necessary justification to the analytical results of the research. The Landsat imagery is necessary to determine the amount of change in the vegetative disposition of the study area. Figure 8 outlines the methodology utilized in the change detection procedure followed by a more descriptive methodology.

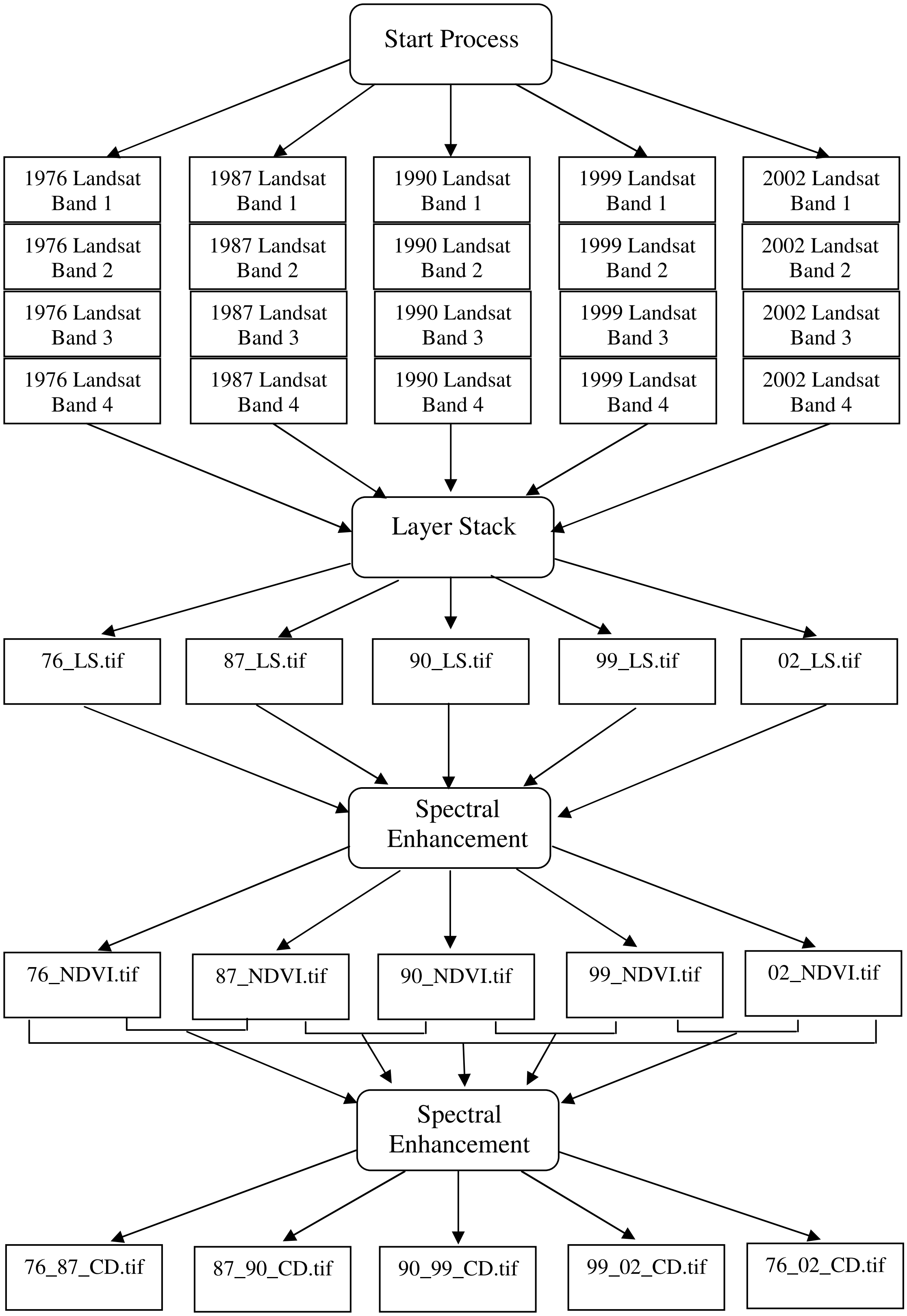


Figure 8: Methodology flow chart illustrating the change detection process.

Five Landsat images ranging in years from 1976 to 2002 were compared to derive the percent change in the vegetative state of the study area. Research of feasible Landsat imagery determined that necessary images were available for Wise County. Once the availability of imagery was ascertained, a contact from the DMLR was established to select a suitable study area. The Flat Gap mining site was selected based upon the permit issuance date. No mining was permitted in the study area before 1983; therefore the 1976 imagery serves as an indicator of the natural vegetative state of the area. The Flat Gap mining site shapefile contains twelve individual mining sites. The Flat Gap mining site shapefile was used to derive shapefiles for the deep, auger, and surface mining methods.

**NDVI CALCULATION AND CLASSIFICATION**

A two-step process using Erdas Imagine 8.7 software was used to derive a NDVI for each year relevant to the study. First, bands 1, 2, 3, and 4 for each year were combined into a single image through the layer stack function of Erdas Imagine. Each image was saved as a tiff file. Next, the spectral enhancement function of Erdas Imagine was performed on each tiff file to derive the NDVI. The derived NDVI represents an unsupervised classification of the study area. NDVI shows the density of plant growth over an area (Weier and Herring 2001). They were saved as tiff files and viewed, analyzed, and compared using ArcMap 8.3.

A total of four analyses were completed using the NDVI images. The first analysis studied the effect of mining as a whole on the vegetative state of the land. The analysis mask and extent were equal to that of the Flat Gap mining shapefile. The remaining three analyses studied the effect each mining method, deep, auger, and surface, had upon the vegetative state of the land. For each analysis, the analysis mask and extent were equal to that of the specific mining method. A cell size of 100 feet was used for each analysis.

Using ArcMap's Spatial Analyst extension, each NDVI tiff file was reclassified to discern between no or unhealthy and healthy vegetated areas. Each NDVI image was reclassified according to the aforementioned properties into the following two categories, -1.0 - 0.4 and 0.4 - 1.0. The resulting raster files contained the same pixel size throughout the study area, thus the same number of cells were present in all images. The classification -1.0 - 0.4 indicates areas of no or non-healthy vegetation, while the classification 0.4 – 1.0 indicates areas of healthy vegetation. Although Weier and Herring (2001) state NDVI values of .2 to .3 indicate shrubbery and grasslands, this research focused on areas with a healthier, denser covering of vegetation. Healthy green vegetation will have an NDVI value of 0.4 or higher (Jensen 1996). The areas of no or non-healthy vegetation were assigned a cell value of 0, and areas of healthy vegetation were assigned a cell value of 1.

The accuracy of the NDVI is of utmost importance to the outcome of this research. Therefore, an accuracy assessment was performed using the methods of Hung and Wu (2005). Detailed 2002 aerial photography with spatial resolution of two feet was used as ground truth to compare to the 2002 NDVI image in the accuracy assessment. A sample size of 204 points was selected by using the normal approximation equation suggested by Fitzpatrick-Lins in 1981: $N = 4 (p) (q) / E^2$ (Hung and Wu 2005). The expected accuracy is 85% with an allowable error of 5%. The overall accuracy was 95.5%. The accuracy assessment was only performed on the 2002 imagery. The same accuracy results are expected and assumed for this research.

**VEGEGETATION CHANGE DETECTION**

In order to suggest that mining is in fact the cause of the loss of vegetation, overall change in the vegetative state of the study area was calculated using Erdas Imagine's Change Detection function. More specifically, the image differencing function compares the NDVI images to calculate where the change in vegetation took place. A variable change of 10% based on the derived NDVI image was used to visually depict the location of the change in vegetation throughout the study area. The change detection depicts both areas of increase and areas of decrease based upon the 10% threshold. Erdas Imagine 8.7 derived the original change detection tiff files, while ArcView 8.3 reclassified the images to the extent of the study area and/or specified mining method.

The exact location in which change occurred is beneficial to ensure that the change actually occurred in times of production. If the vegetation decreased at a time when no mining was performed, then other factors would be the causes of the vegetative loss. In order to justify the alteration of the land by the coal mining industry, the vegetation, expressed as the number of NDVI cells with values of 0.4 – 1.0 was compared to the date mining was permitted to commence within the mining site with the most change. Percent change of vegetation was calculated and compared to the percent change of coal production throughout the entire county. Each result acquired through the spatial analysis of the Landsat imagery was necessary in order to compare the environmental status of the study area to the economic factors previously collected. Graphical and visual comparison of the datasets offers insight into the economical and environmental impacts of the coal mining industry.

# CHAPTER 4: ANALYSIS RESULTS AND DISCUSSION

Coal mining was permitted by the DMLR throughout the study area beginning in 1983 and continues today. Through the acquisition and analysis of multiple datasets and images, the following results were achieved and concluded.

## NDVI CALCULATION AND CLASSIFICATION

Analysis of the Landsat imagery indicates during the study period the natural vegetative state of the land was significantly disturbed. In 1976, before any recorded mining commenced, over seventy-six percent (76%) of the study area consisted of healthy vegetation with an NDVI value of 0.4 or higher as illustrated in Figure 9. As time advanced and mining commenced, significant changes occurred throughout the study area as illustrated by Figures 10, 11, 12, and 13. Figure 10 illustrates the status and locations of healthy vegetation (91%) of the study area in 1987. Figure 11 illustrates the status and locations of healthy vegetation (88%) of the study area in 1990. Figure 12 illustrates the status and locations of healthy vegetation (64%) of the study area in 1999. Figure 13 illustrates the status and locations of healthy vegetation (39%) of the study area in 2002. To ensure the validity of these findings, an accuracy assessment of the 2002 NDVI was compared to 2002 orthophotography of the study area. Table 4 is the error matrix, along with the overall accuracy, which was assessed at 95.5%, and the $K_{hat}$ coefficient, which was assessed at 91.2%

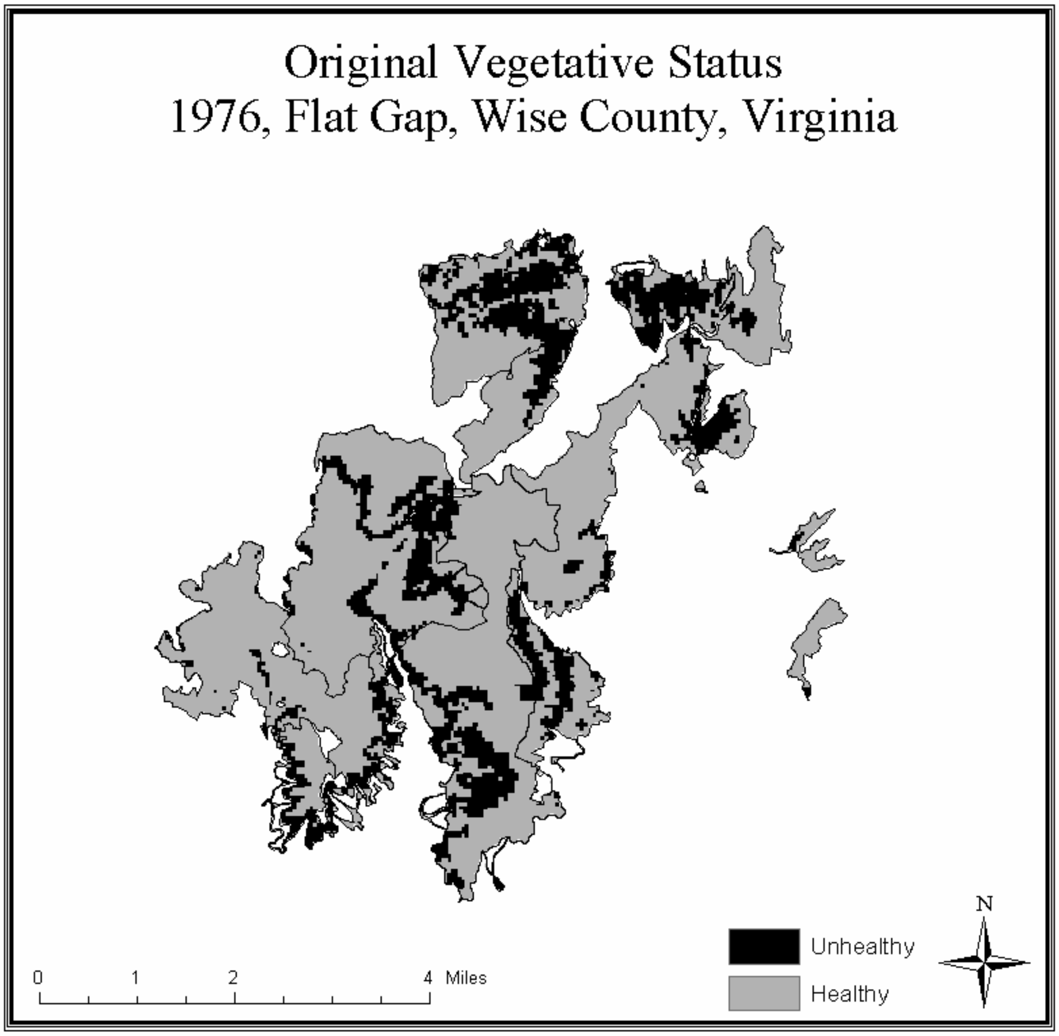


Figure 9: Original Vegetative Status. Illustration depicts areas of healthy and unhealthy vegetation in 1976 as derived from the NDVI.

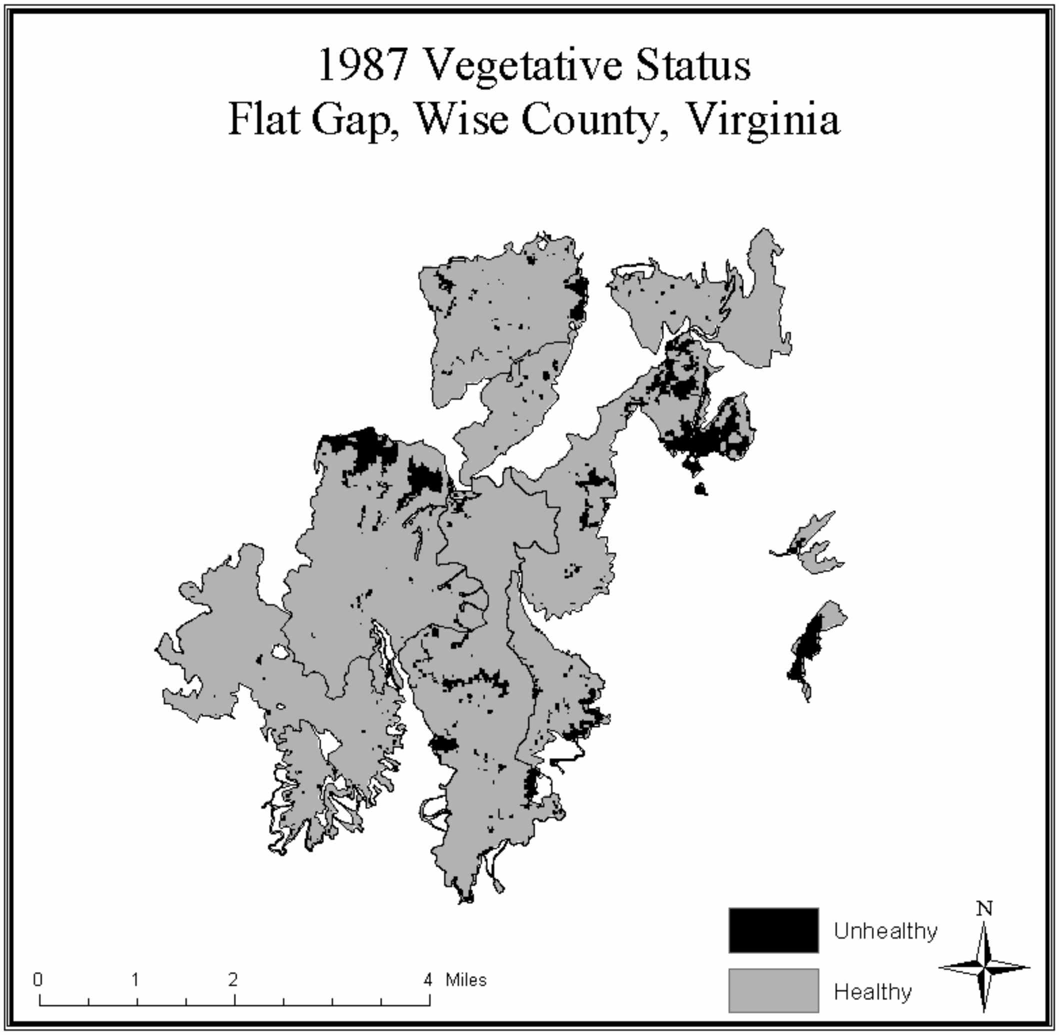


Figure 10: 1987 NDVI. Illustration depicts areas of healthy and unhealthy vegetation as derived from the NDVI.

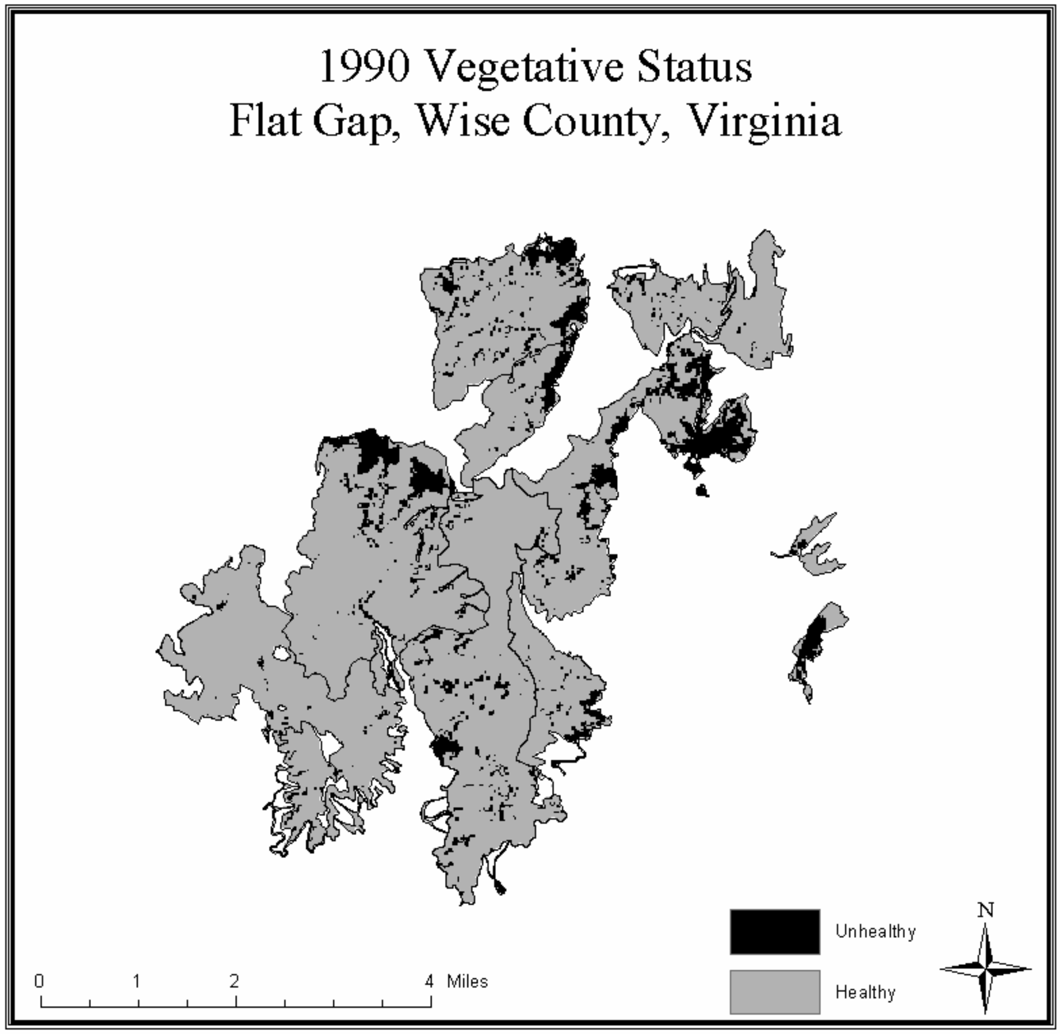


Figure 11: 1990 NDVI. Illustration depicts the areas of healthy and unhealthy vegetation as derived from the NDVI.

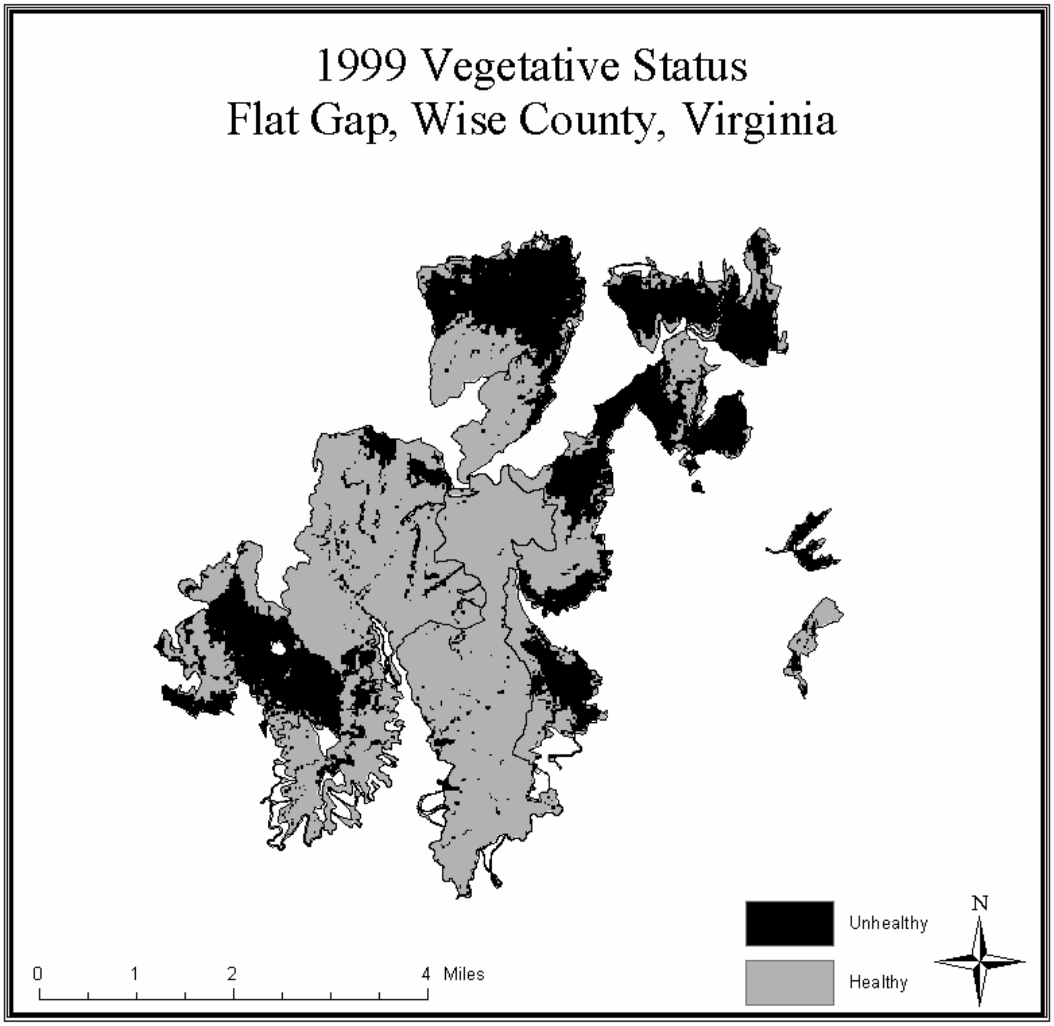


Figure 12: 1999 NDVI. Illustration depicts areas of healthy and unhealthy vegetation as derived from the NDVI.

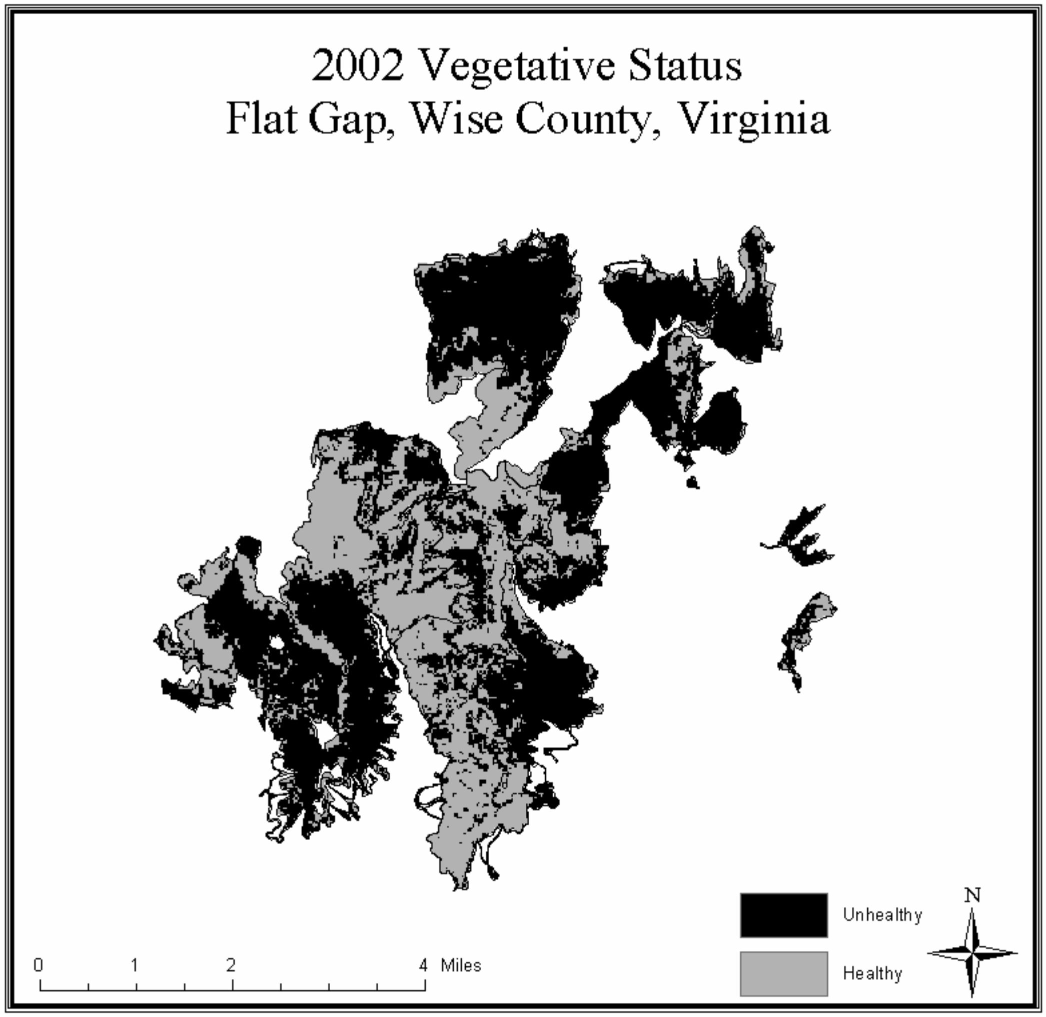


Figure 13: 2002 NDVI. Illustration depicts areas of healthy and unhealthy vegetation as derived from the NDVI.

Table 4: Accuracy Assessment Matrix. Accuracy assessment performed on 2002 NDVI resulting in 95.5% overall accuracy, the $K_{hat}$ coefficient is 91.2%.

| | Ground Truth | | |
|---|---|---|---|
| NDVI | VEGETATION | NO VEGETATION | ROW |
| VEGETATION | 93 | 9 | 102 |
| NO VEGETATION | 0 | 102 | 102 |
| COLUMN | 93 | 111 | 204 |

**VEGETATION CHANGE AND COAL MINING**

Throughout the study period, as mining occurred the total area of healthy vegetation decreased by fifty-two percent (52%) as a direct result of the mining industry (Figure 14 and Figure 15). It was concluded that coal mining was the factor most closely related to the loss of vegetation over the study area through comparison of the location of change and the permitted mining date of the site with the most loss of vegetation. In each comparison, 1976 – 1987, 1987 – 1990, 1990 – 1999, and 1999 – 2002, the site with the most loss of vegetation was permitted to begin mining within that specified time frame. Figures 16 through 19 support this finding.

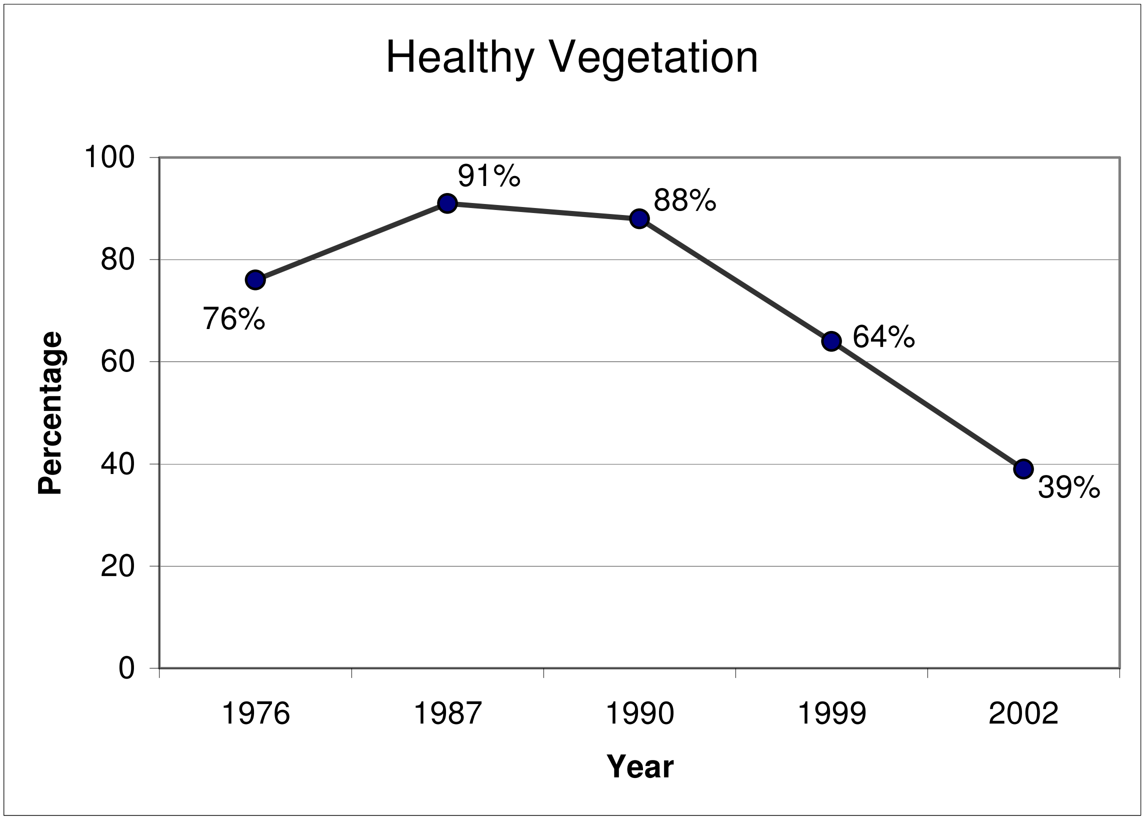


Figure 14: 1976 – 2002 Healthy Vegetation Comparison Graph.

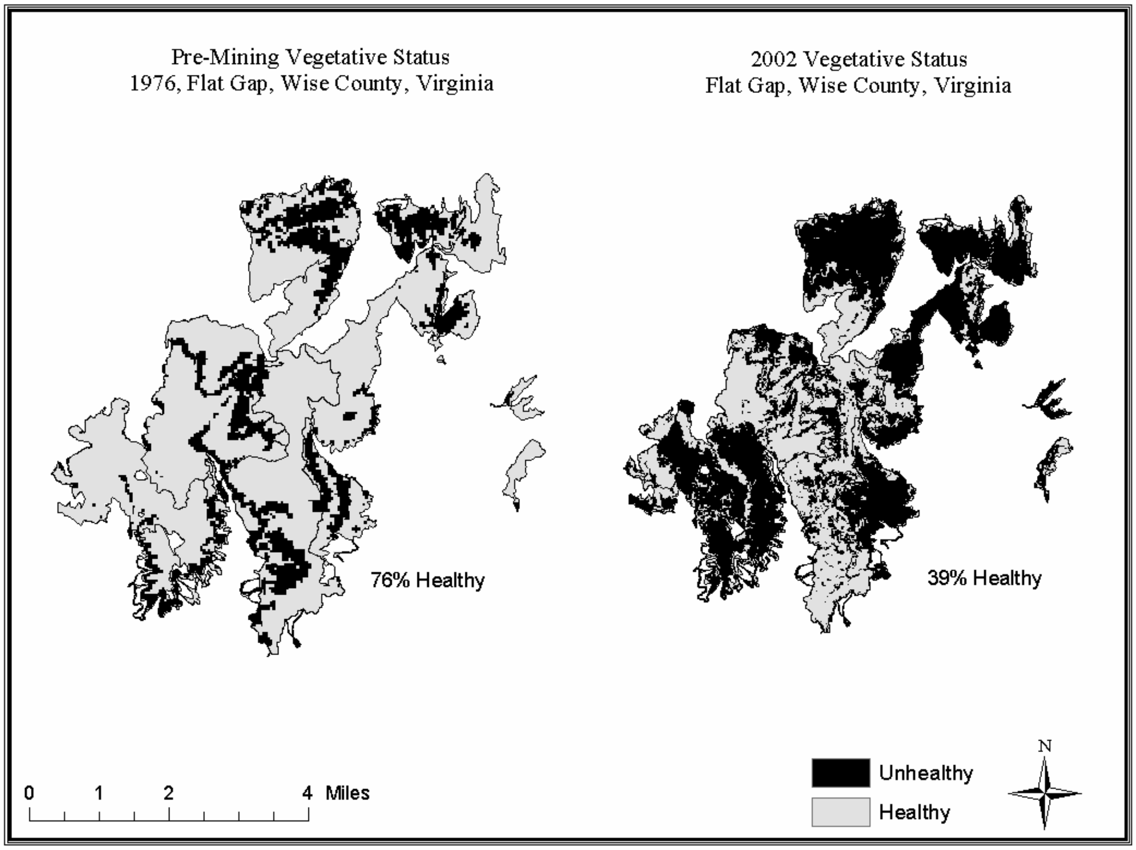


Figure 15: 1976 – 2002 Vegetation Comparison. Illustration provides a comparison of the pre-mining and 2002 vegetative status of the study area.

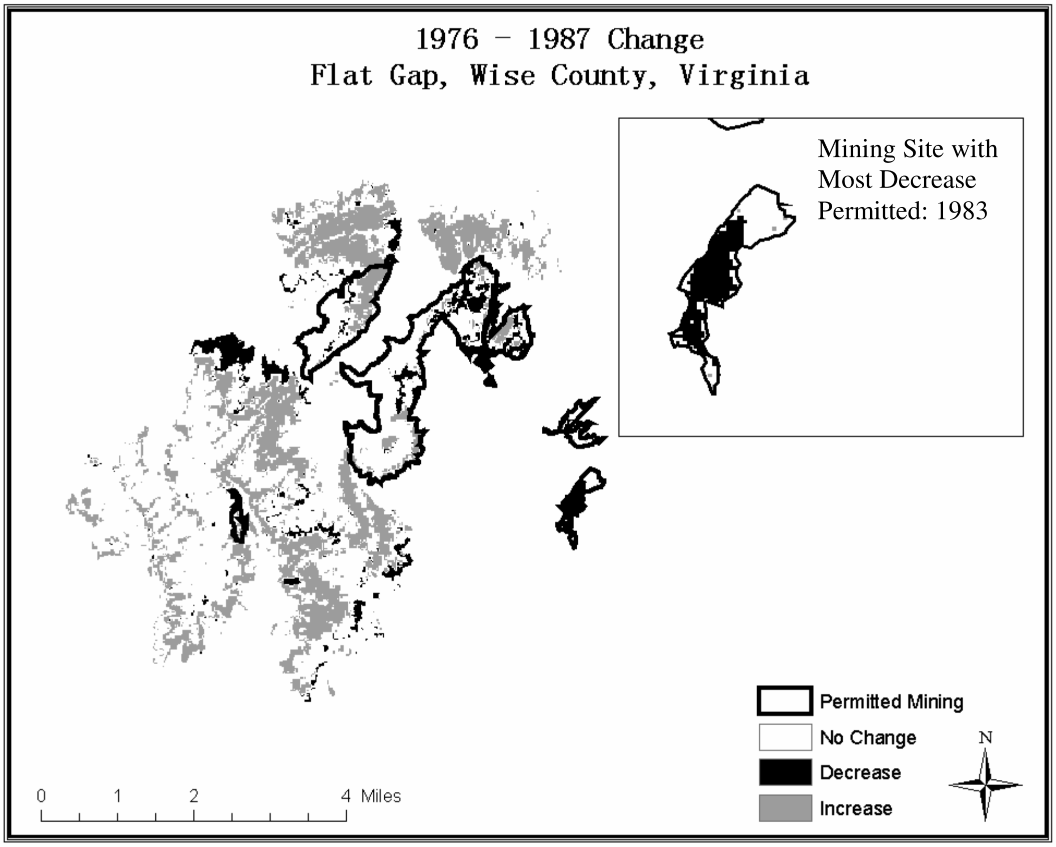


Figure 16: 1976 – 1987 Vegetation Change. Illustrates the change in vegetation during the time period 1976 – 1987 in Flat Gap. Change calculated from NDVI using Erdas Imagine's change detection function.

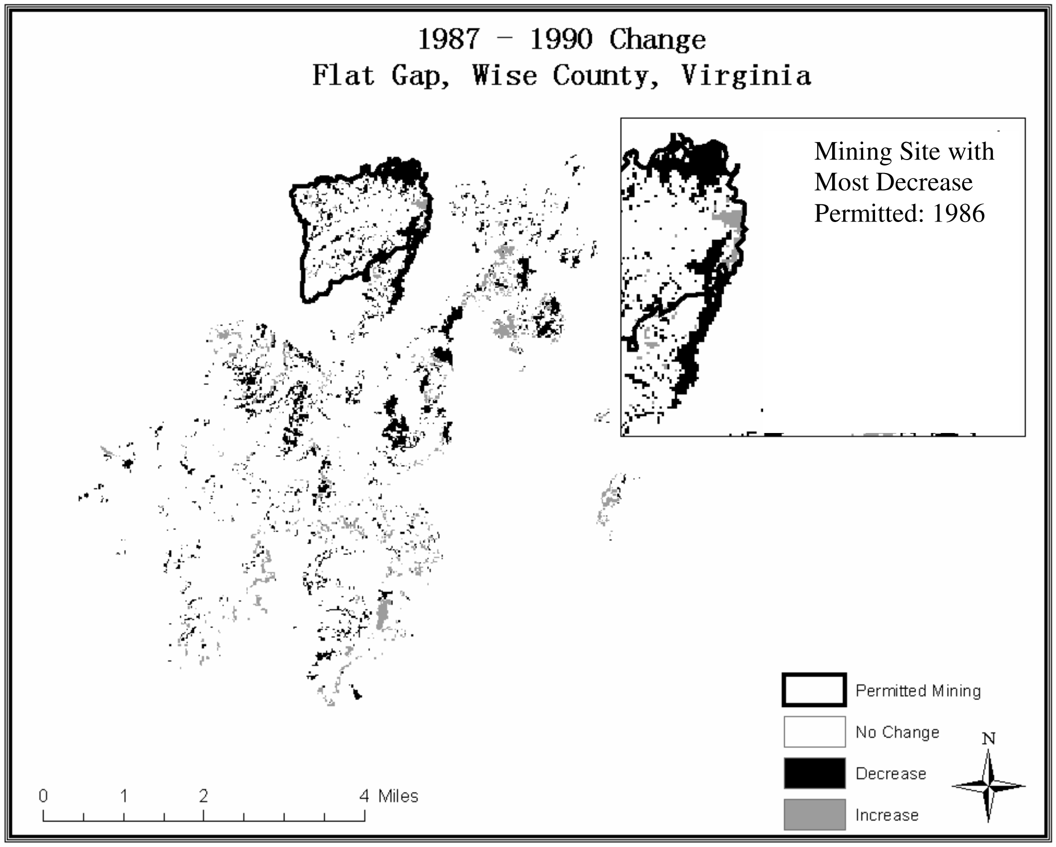


Figure 17: 1987 – 1990 Vegetation Change. Illustrates the change in vegetation during the time period 1987 – 1990 in Flat Gap. Change calculated from NDVI using Erdas Imagine's change detection function.

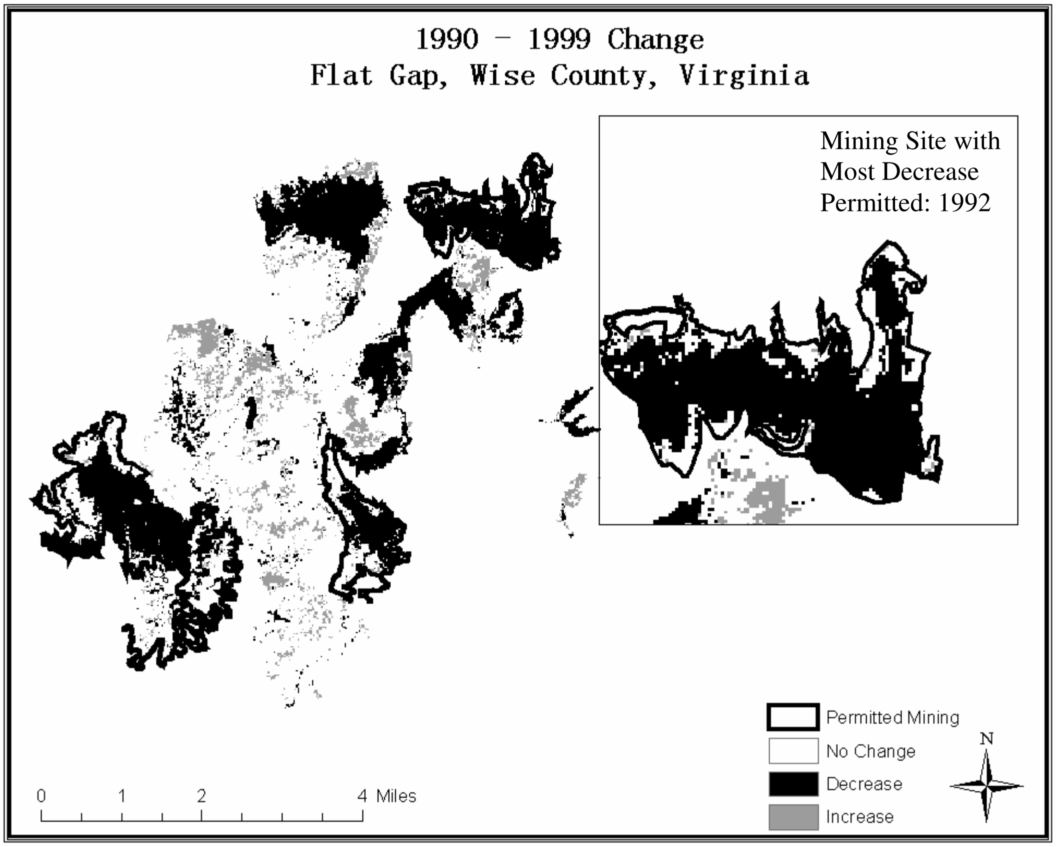


Figure 18: 1990 – 1999 Vegetation Change. Illustrates the change in vegetation during the time period 1990 – 1999 in Flat Gap. Change calculated from NDVI using Erdas Imagine's change detection function.

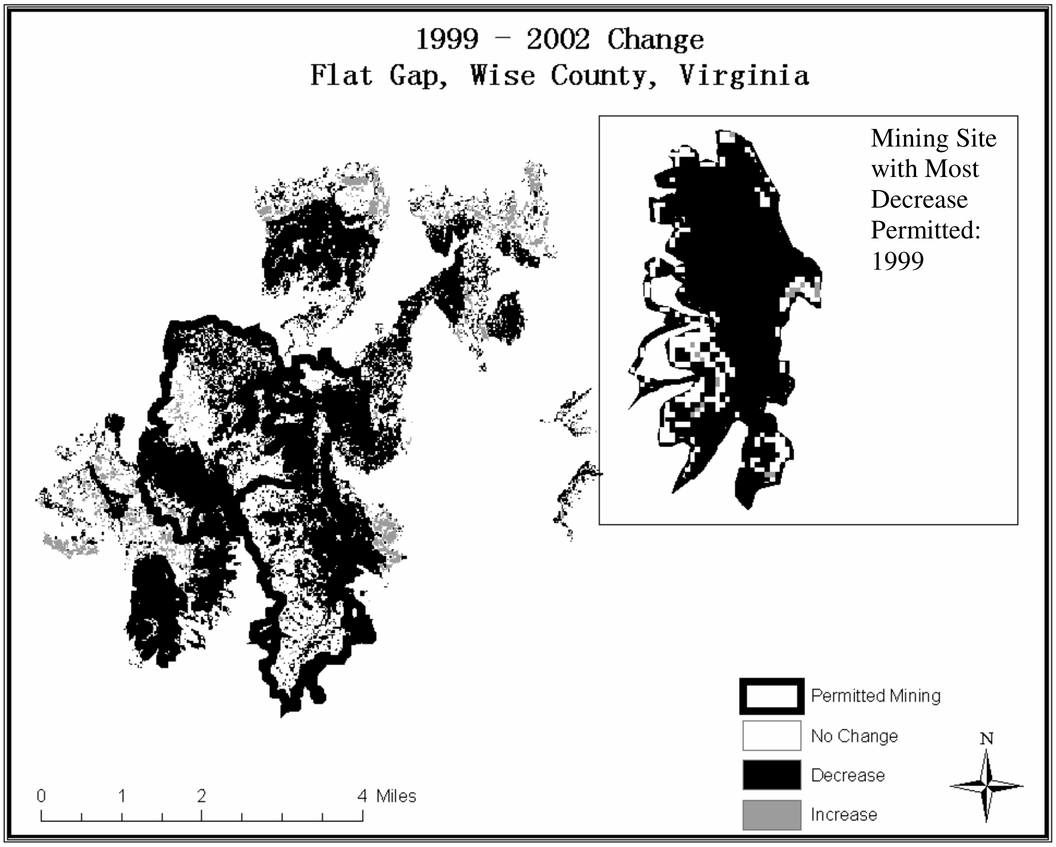


Figure 19: 1999 – 2002 Vegetation Change. Illustrates the change in vegetation during the time period 1999 – 2002 in Flat Gap. Change calculated from NDVI using Erdas Imagine's change detection function.

In direct relation to the coal mining industry, Table 5 discloses the change in vegetation throughout the study area in comparison to the coal mining production trends in Wise County and to the number of established sites over the study area. Wise County production change indicates the increase or decrease in the amount of coal produced for each time frame. The study area vegetation change percentage is derived from change detection images consisting of a 10% vegetation change threshold. Each timeframe consists of both a loss and gain of healthy vegetation throughout the study area. The loss in vegetation is attributed to the removal of soil and vegetation to extract coal from the

Table 5: Wise County Production Versus Study Area Vegetation Change. A graphical comparison of the Wise County Production Trends, Vegetation Status of study area, and number of sites established over the study area during each time frame.

| Comparison Years | Wise County Coal Production Change (%) | Study Area Vegetation Change (%) | Mining Sites Established (study area) |
|---|---|---|---|
| 1976 – 1987 | + 3.0 | -7.0 and +28.3 | 4 |
| 1987 – 1990 | - 5.8 | -9.8 and +4.1 | 1 |
| 1990 – 1999 | + 13.0 | -33.0 and +7.5 | 4 |
| 1999 – 2002 | + 12.0 | -50.0 and +5.8 | 3 |
| 1976 – 2002 | + 23.0 | -57.0 and + 7.9 | 12 |

earth. The gain of vegetation is attributed to the planting and reclamation of the mine site.

Research indicates that at the onset of mining, a time existed when vegetation actually increased despite the permitted mining status of the land (Figure 20). Analysis of the study area suggests that over ninety percent (90%) of the study area was covered by healthy vegetation in 1987. This is a 28.3 percent increase in healthy vegetation over the study area as compared to 1976.

Though the seasonal or annual change in weather may affect the vegetation amount, the satellite imagery suggested a slight trend of vegetation increase during time of constant coal production. This increase in vegetation could be explained by the sequences among mining activities. Aschmann states that there are four

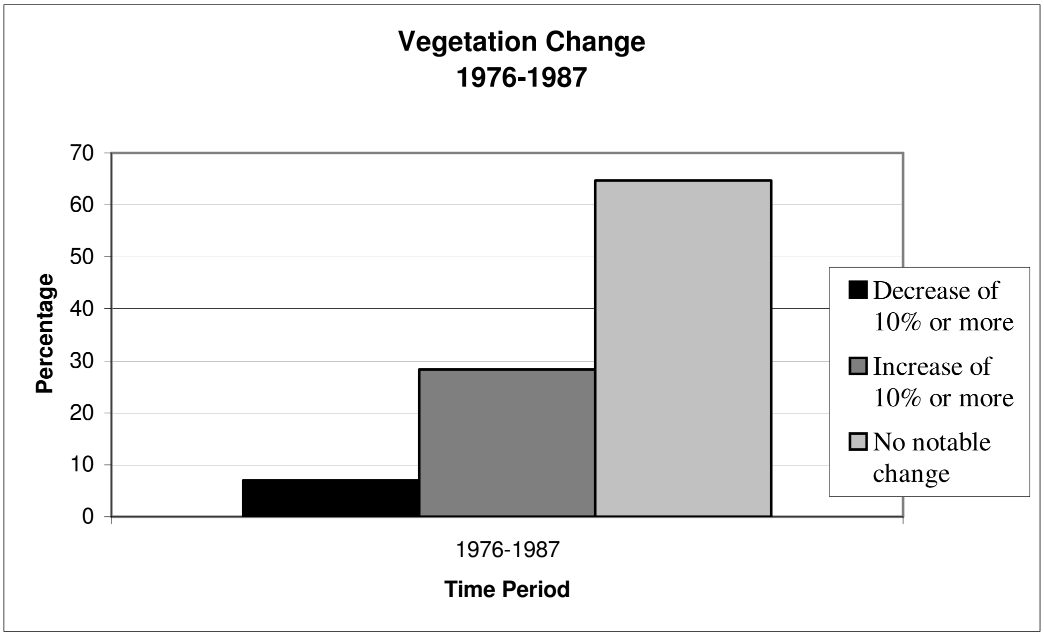


Figure 20: Increase in Vegetation. Chart illustrates the increase in vegetation from 1976 to 1987, the time frame when mining is first permitted.

stages of the development of a mine: prospecting and exploration, investment and development, stable operation, alteration of vegetation (Sluyter 1998). During the second stage vegetation is removed from the mining site. The vegetation is removed over the specific area in which the coal lies in addition to the areas which will accommodate machinery such as conveyor belts, coal washing systems, coal slurry ponds, and coal haul roads (Wooten, 2005.) Once the site is prepared for production to begin, further vegetation is not disturbed. In fact, vegetation will begin to grow in areas of the mine site such as around the ponds, machinery, and roads. The argument may arise that the vegetation is not healthy. However, analysis of the NDVI of the Flat Gap mining site reveals that healthy vegetation lies throughout the site during times of constant production. Furthermore, analysis shows that healthy vegetation increased in some parts of the study area in times of highest production (Figure 21). Healthy vegetation is defined as having an NDVI value of 0.4 or higher, which represents dense vegetation (Jensen 1996).

Furthermore, the research indicates that an inverse relationship exists between tonnage and vegetation (Figure 22) when there is a significant increase in coal production, which is expressed as tonnage. At times, however, when tonnage remains relatively the same, vegetation is not significantly altered. Although healthy vegetation exists throughout the study area, during times of high production a substantial decrease in vegetation results. The study area lost 57% of the natural vegetation from 1976 – 2002.

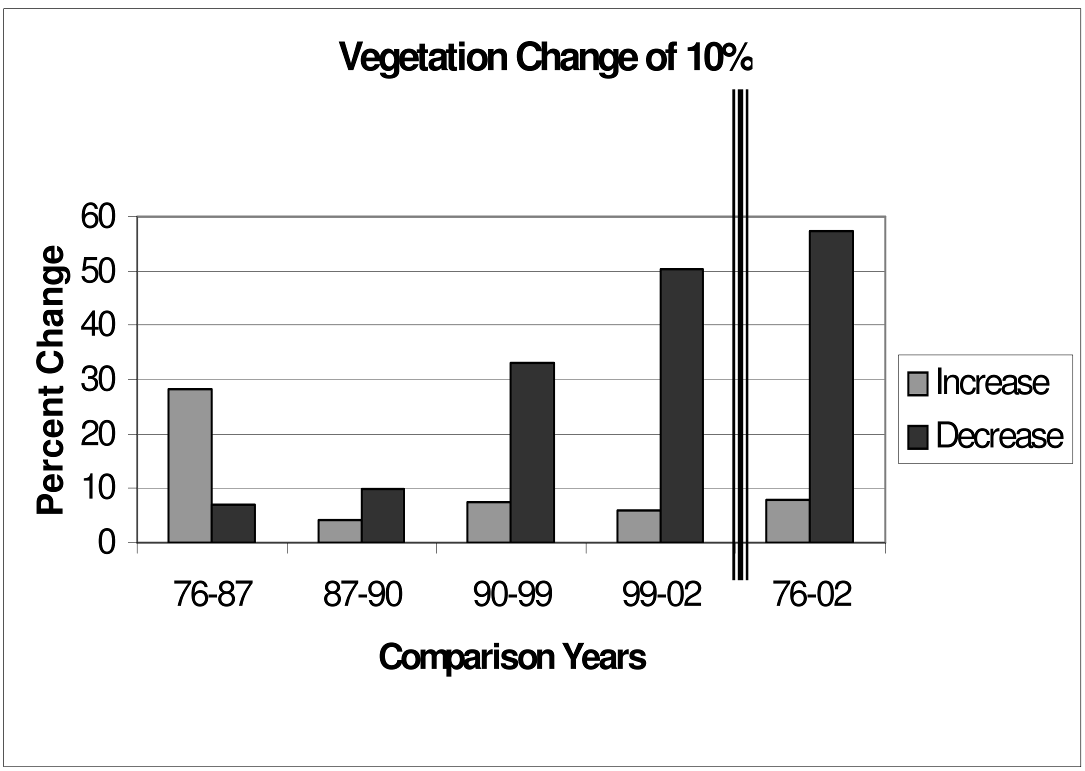


Figure 21: Vegetation Change of 10%. Graph represents the percentage of increase and decrease in vegetation for each specified time period. Change is defined as being a 10% or more increase or decrease.

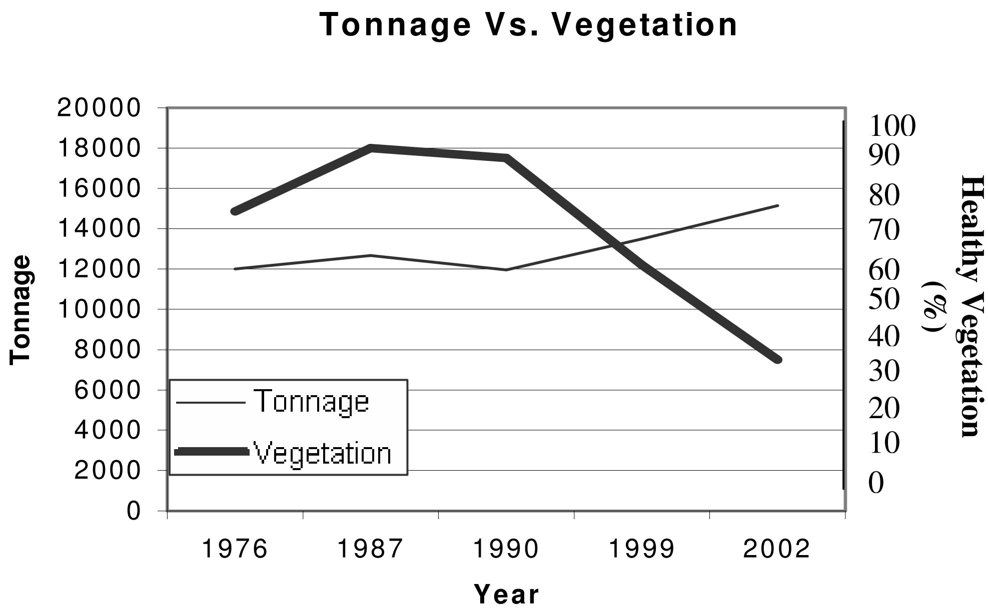


Figure 22: Tonnage Versus Vegetation. Analytical result indicating an inverse relationship exists between tonnage and vegetation.

The various methods of coal extraction exhibit different levels of stress upon the natural state of the land (Figure 23). Analysis indicates that the underground mining method introduces the most stress upon the land. Analysis of the study area indicates that during the time period 1976 – 2002 the areas affected by the underground mining method lost a total of 62%, areas affected by surface mining lost 46%, and areas affected by auger mining lost 43% of the original healthy vegetation covering the same area. Through surface and auger mining, stress is introduced to the land but after the initial preparation for the extraction of the mineral, healthy vegetation will begin to survive even as coal is being mined. The underground mining method requires workers to dig rooms and tunnels in the earth. The refuse, or soil removed to create the rooms and tunnels, is often spread and heaped around the mine site. The refuse is often rocky soil in which healthy vegetation will not strive. Therefore, although the underground mining

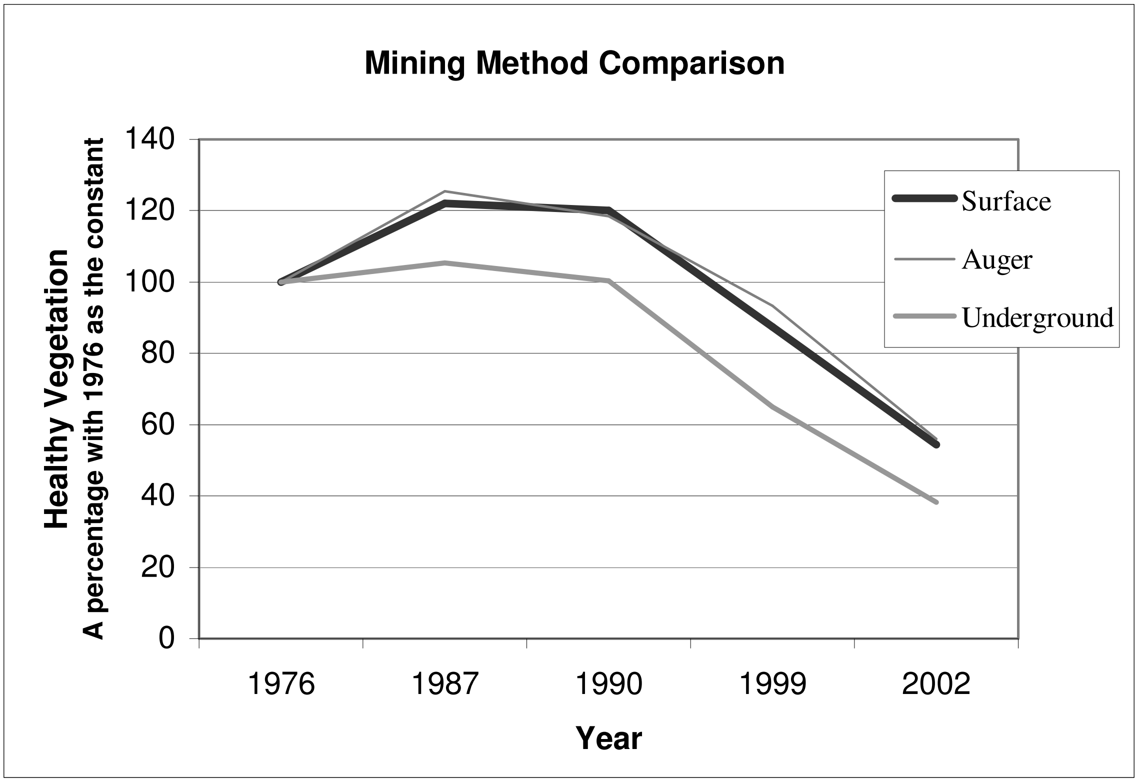


Figure 23: Mining Method Comparison. A comparison of the impact each mining method used to extract coal from the earth imparts upon the natural vegetative state of the land. The year 1976 is used as the baseline for the analysis; other years are expressed as percentage of the year 1976.

method does not remove the topsoil from the site, rocky soil may cover the healthy topsoil impeding any growth of vegetation during the mining process.

Although the research suggests that vegetation is lost due to the mining industry, it is important to consider the economic impacts the industry imposes on the community. From 1978 – 2004 an average of 88 coal mining companies have been located in Wise County and have employed an average of 3,600 individuals. Additionally, nearly $89,000,000 has been assessed through the coal severance tax in Wise County from 1979 through 2004. Table 6 summarizes the annual revenue acquired by the county through the severance taxation process.

Table 6: Severance Tax. Summarizes the annual revenues paid by the coal industry to Wise County.

| | Tax Collected | General Operating | Water and Sewer | CEDA | Coal Haul Roads |
|---|---|---|---|---|---|
| **1992** | 2,908,257.71 | 1,454,128.86 | 363,532.21 | 363,532.21 | 727,064.43 |
| **1993** | 2,873,006.38 | 1,436,503.19 | 359,125.80 | 359,125.80 | 718,251.60 |
| **1994** | 3,242,172.66 | 1,621,086.33 | 405,271.58 | 405,271.58 | 810,543.17 |
| **1995** | 3,124,206.41 | 1,562,103.21 | 390,525.80 | 390,525.80 | 781,051.60 |
| **1996** | 3,143,825.05 | 1,571,912.53 | 392,978.13 | 392,978.13 | 785,956.26 |
| **1997** | 3,374,193.12 | 1,687,096.56 | 421,774.14 | 421,774.14 | 843,548.28 |
| **1998** | 3,141,912.28 | 1,570,956.14 | 392,739.04 | 392,739.04 | 785,478.07 |
| **1999** | 2,971,994.05 | 1,485,997.03 | 371,499.26 | 371,499.26 | 742,998.51 |
| **2000** | 3,003,506.46 | 1,501,753.23 | 375,438.31 | 375,438.31 | 750,876.62 |
| **2001** | 3,772,941.98 | 1,886,470.99 | 471,617.75 | 471,617.75 | 943,235.50 |
| **2002** | 3,371,778.78 | 1,685,889.39 | 421,472.35 | 421,472.35 | 842,944.70 |
| **1979 - 2004** | **88,939,901.12** | **44,469,950.56** | **11,117,487.64** | **11,117,487.64** | **22,234,975.28** |

## LIMITATIONS

Several limitations may have an effect upon the outcome of this research. First, historical land use data is not available for the study site. The only indicator of land use is the Landsat imagery collected. There is no record of previous mining to the site; however, logging may have removed vegetation from the land at some time. Next, the lack of complete economic data sets prevents the complete economic analysis of the research. Historic annual tax revenue data is not available prior to 1992 making it impossible to conclude with certainty a direct relationship among tax revenue, vegetation, production, and employment. Next, this research only analyzes active mine sites in which no post-mine reclamation has been achieved. However, it is understood that through SMCRA and other mining and reclamation regulations set forth by federal mandate upon completion of mining, the site will be restored to the permitted post-mine land-use type and will be restored to a reasonable healthy vegetative status.

## CHAPTER 5: CONCLUSION

In conclusion, research of the Flat Gap Mining Site in collaboration with various economic datasets suggests that the natural vegetative state of the land is altered by the coal mining industry. Analysis suggests a direct relationship between coal production and vegetation lost, but an inverse relationship between coal production and the percentage of healthy vegetation. The underground mining method introduces the most stress upon the natural state of the land. The coal mining industry supplies revenue in the form of severance taxes that are necessary to sustain Wise County, Virginia.

While research cannot contest the fact that coal mining alters the natural vegetative state of the land, research does provide for the economic benefits the industry imposes upon the county. In 2004 alone, Wise County collected over $4.5 million in severance taxes from the coal industry. Despite the fact that overall coal industry employment has decreased over the years, the unemployment rate of the county continues to decrease since 1990. Individuals may not be working directly for the coal industry but may be sub-contracted by the industry to work on mining equipment, reclamation, and technological advances. It is also important to acknowledge that the coal mining industry offers assistance to local individuals and organizations throughout the county. In most cases, the mining industry chooses not to publicly disclose these acts. Some of these acts include paving public school parking lots, donating monetary funds to civic organizations, and so forth.

This research may be expanded throughout the reclamation of the study site. Upon completion of the reclamation process, the research may be expanded to determine if the reclaimed site consists of the same type and amount of healthy vegetation, or biomass, as the original, pre-mined site. The economic aspect of the study may be expanded to determine the number of jobs and amount of severance tax revenue lost once the site is closed.

The methods used in this research are applicable to study the alteration of vegetation under any man-made or natural circumstance. The methods may be used to determine the percent change of vegetation over a particular area due to natural disasters such as wildfires or hurricanes, or man-made circumstances such as mining, logging, overgrazing, and economic development projects. While the methods may be applicable to any region, the NDVI values used by this research may not be acceptable for all regions and all seasons. The study site of this research consisted of heavily forested, densely vegetated land. In order to study the vegetative change of an area consisting of grasslands or dessert regions, the breakpoint in the NDVI value should be less than 0.4 and greater than 0.2; in order to study the health of a tropical rain forest, the NDVI value should be 0.6 or greater.

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