

Geospatial Analysis of Coal Mining Impacts on West Virginia's Environment

ABSTRACT

Ever since the discovery of coal in the state of West Virginia, coal continues to find widespread use with growing impacts on the environment. Coal mining techniques of surface, underground, and mountain top clearing trigger degradation of water quality, damage to adjacent streams and watersheds, disturbance of mountain ecosystem and the loss of open space and land resources. Notwithstanding these impacts, very little has been done in the literature to apply a geospatial approach in pinpointing the scale and frequency of disturbances, and the impacts of coal mining activities on West Virginia's environment. In terms of methodology, this research will fill that void in the literature using a mix scale approach of GIS, satellite photo images and primary data connected to descriptive statistics by analyzing the impacts of mining in the study area. Emphasis are on the issues, factors and efforts to deal with the problems. The result point to changes in coal production, and widespread disturbances resulting in the loss of land and open space, impacts on mountain ecosystem, impacts from aquatic toxicity, impacts on water quality and loss of human lives. The spatial analysis reveal the dispersion of mining activities onto sensitive environments (open space, sensitive aquatic environments of streams and watersheds and mountain ecosystems). While these problems are attributed to socio-economic elements, the current efforts have done little to contain the scale of degradation. To remedy the problems, the paper offered various recommendations ranging from stringent policy to regular mapping of mining impacts in the study area.

Keywords: west virginia, coal mining impacts, environmental degradation, GIS, factors, mountain top clearance

1.0 INTRODUCTION

1.1 Background Information and the Issues

For over a century, a natural resource has played vital part in the economy of west virginia. From the genesis of the state's history, coal remained the major resource powering the economy (Bureau of Business and Economic Research 2010). Coal mining generated jobs for the inhabitants of the state, and proceeds from the coal tax accounted for a large part

of the state's revenue (McIlmoil 2010; 2012). With its history, mining operations in the state accounted for the production of approximately, 13.4 billion tons of coal between 1880 to 2009. Being a center piece of west virginia's economy, in the 2010 fiscal year alone, the coal industry doled out about \$1.6 billion in salaries (O'Leray 2011). In the process, West Virginia has for decades relied on the coal mining sector as a central portion of its economy. But as of today, coal deposit remains in constant decline with reccurent ecosystem degradation (O'Leray 2011, EPA 2011; MHST 2010).

Apart from the economic benefits, mountaintop removal (MTR) and other kinds of surface mining in which machines and explosives demolish mountainsides and the environment(Yan 2010); accounted for about 42 percent of all coal extracted in 2007 in west Virginia. This is up from 31 percent a decade earlier. In that setting, ecological externalities from mining continue to degrade stream water quality and the surrounding ecosystem. As of 1986 to 2001, about 2,636 MTR permits were distributed in the state (West Virginia Rivers Coalition 2013). With much of the mining activities occurring within the vicinity of sensitive watersheds and habitats for rare species. Widespread explosives and giant machines used by the industry in the state are destroying the biodiversity rich Appalachian mountain peaks to extract coal. Accordingly, more than 16,000 safety violations were reported by state officials in 2009 with impacts on the environment (MHST 2010). Another issue is the presence of about 4,391 abandoned mine land in the study area; among them, about 1,180 have experienced water degradation issues over the years (McIlmoil 2010).

Noticing the gravity of the problem, very little has been done to spot the frequency and scale of the problems with the advances in spatial technology such as Geographic Information Systems (GIS) in west virginia. While GIS has found widespread appeal in other studies targetting watershed degradation and landscape change in various works of Merem and Twumasi (2005a,b,c); (2006). (2008); (2009); (2010); (2011a.b.c.d); (2012 a,b,c); Merem (2013). Previous studies along those lines by Bisaws (2002) Prakash (2007); Usery (2004); and Khawlie (2005) reinforce the essence of these themes elsewhere. Another relevant work consits of Repetto's (1989) work "wasting assests" and "accounting for subsoil natural resources assests" by the US Bureau of Economic Analysis (2000). Studies rooted in analytical tools comprise of those O'Brien (1992); Ott (1995); and Robinson (1998). Despite these array of studies, very little in the litterature has focused solely on the ecological impact analysis of coal mining in west Virginia using GIS.

Considering this void in the litterature, there remains widespread growth in the number of mining operations in various areas of the state at the expense of environmental welfare (Figure 1.1). This has resulted in concerns on the impacts of coal mining and the wastes generated coupled with the discharge of toxic materials of barium, arsenic and selenium from coal field sites in southWest Virginia and moutain top removal activities. The effects ranged from physiological abnormalities in fish and the risks of cancer over the years and non-point sources of pollution, impairment of stream and watershed quality, land loss, vegetation decline and numerous environmental health threats that impede water quality (Appalachian Vocies 2013 a,b,c; Chhotray 2008; Lindberg 2011). The problems of mining hazards and the threats to the ecosystem do not operate in a vacuum; they emanate from policy defects and socio-economic elements. In light of current damages brought by coal mining, this paper will fill that void in the research.

1.2 Purpose and Organization

This paper analyzes the growing impacts of coal mining activities on West Virginia's environment using Geographic Information Systems (GIS). The emphasis are on the issues, factors fuelling the problems, environmental analysis and efforts to deal with the problems and future lines of action. The paper has four objectives. The first aim of the paper focuses

on the use of spatial technology in analyzing effects of coal mining activities on the environment, while the second objective aims to generate a tool for effective management of environmental resources. The third objective is to design a decision support tool. The fourth objective is to contribute to the literature. The sections in the paper consist of the introduction, the materials and methods portion, the results and discussions, as well as the conclusions.

2. MATERIAL AND METHODS

2.1 The Study Area

The study area of West Virginia is located along the American Heartland with over 55 counties (Figure 1.2). The state has numerous watersheds and wetlands (Figs 1.2, 2.0, 2.1). With a population of 1.8 million people in 2009, the state boasts of immeasurable sceneries of sparkling water, fresh air and opulent green mountains, streams and watersheds. In terms of biodiversity, the West Virginia's northern panhandle contains the most diverse temperate hardwood forest in the globe. The hillsides provide habitats to numerous organisms in the southern Appalachians than in any other forest ecosystem in the world. Despite the vast presence of salamander species than any place on the planet and nesting grounds for neotropical migratory birds and web of biodiversity habitats (Appalachian Voices 2012 a). This tapestry of species richness in the state are now being threatened by the growing impacts of coal mining mountain top removal practices as shown in Figure 1.1 (Lindberg 2011; Winscombe 2013)..



Fig. 1.0 The Study Area



Fig. 1.1 Image of Moutaintop Removal Mining

Being one of the major resources in West Virginia's economy (McIlmoil 2010; 2012), coal occurs in 53 of West Virginia's 55 counties (MHST 2012). With the largest part of the electricity in the area originating from coal-fired power plants. The economic benefits of the industry stems from its contribution to tax revenue generation which stood at \$684 million or 10 percent of the total in 2008 (O'Leary 2011).

Additionally, conventional mining operation accounts for 8.2 percent or \$5.1 billion of the state's Gross Demestic Product in 2009 (O'Leary 2011). Prompted largely by the growing

cost of oil in the market place and energy dependent way of life of many in the United States and elsewhere. the lust for coal soared over the years. For more on the economic significance of coal in the state, see Tables 1,1.2, and 1.3.

In opening decades of the 21st century, mining safety and ecological concerns have increased the challenges facing the state whose coal continues to sustain the economic engines in other places. The environmental impact of coal production has become so pronounced that there are now large presence of heavy metals in surface and ground water adjacent to mining fields (Appalachian Voices 2012). As mentioned before, physiological abnormalities and morbidity in fish species and risks to human health are a common occurrence due to large concentration of toxic residues in adjoining streams and watersheds of the state where coal mining is prominent (Lindsberg 2011). Compounding the matter, is the well known fact that much of the coal produced in the state of West virginia end up being shipped to neighboring states, thereby making west virginia the shadow ecology of the receiving steas. With very little understanding of the gravity of accumulated impacts, GIS anlysis provides opportunities for understanding the spatial patterns of mining impacts on fragile waterbodies including watersheds and the environment. Applying that knowledge in practice, is highly essential in dealing with the challenges of ecological disturbances in the study area.

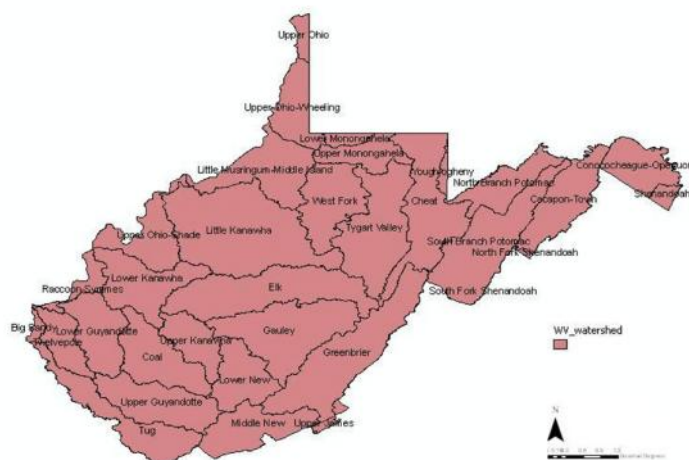


Fig.1.2 The Watersheds of West Virginia Adjacent to Coal fields

Table 1 The Economic Importance of Coal in West Virginia in 2008

Economic Impact of Coal Mining NAICIS 2121 In The West Virginia Economy 2008. (2008 Dollars)			
Variables	Direct	Indirect and Induced	Total
Best Volume sales, Billions \$	\$7.45	\$12,30	\$19.78
Total Value Added billions \$	\$4.06	\$1.87	\$5.93
Employee Compensation	\$1.95	\$0.87	\$2.82
Employment jobs	20,500	25,600	46,000

Source: The Bureau of Business and Economics Research, 2010. West Virginia University

Table 1.2 Employment Aspect of the Economic Impacts of Coal Mining

Economic Impact of Coal Mining NAICIS 2121 In The West Virginia Economy 2008.			Employment
Variables	Direct	Indirect and Induced	Total
Ag, Forestry, Fish& Hunting	0	880	880

Mining	20,500	980	21,480
Utilities, Transport and Warehousing	0	2300	2,300
Construction	0	300	300
Manufacturing	0	780	780
Whole Sale	0	1,000	1000
Retail Trade	0	4,000	4000
Info, Finance, Insurance, & Real Estate	0	2,600	2600
Services	0	12,400	12,400
Government	0	270	270
Total	20,500	25,510	46,010

Source; Bureau of economic Research , West Virginia University 2010

Table 1.3 Heavy Dependence On Extractive Industries For Jobs In West Virginia

County	Mining Jobs Average Share of Total , 1969-2009 %	Population 2009
Boone	51	24,709
McDowell	39	22,398
Wyoming	38	23,304
Mingo	26	26,387
Logan	25	35,498
Calhoun	24	7,118
Gilmer	24	6,824
Nicholas	23	26,213
Barbour	20	15,758
Clay	19	10,022
Roane	19	14,870
Grant	17	11,833
Webster	15	9,444
Doddridge	14	7,202

Source: O' Leary 2011.

2.2 Methodology

In terms of methodology, the paper adopts a mix scale approach involving descriptive statistics and primary data connected to geospatial technology. The spatial information for the research was obtained from the West Virginia On line Technical Data, the National Aeronautic and Space Administration (NASA), West Virginia GIS Clearing House, The Governemnt of West Virginia, the West Virginia Department of Natural Resources office, the United States Environmental Protection Agency (EPA), and the US Geological Services (USGS). The West Virgina office of Mines' Health, Safety and Training (MHST) provided coal data for the periods of 1996, 1997, 2002 and 2010. Federal geographic identifier codes for the much of the counties of west Virginia including the coal producing area were used to geo-code the information contained in the data sets. The spatial data also came from land-use capability information, wetlands, mine lands, multitemporal satelite photo images, watersheds and streams and classification maps of the study area. This information was analyzed with basic descriptive statistics, and GIS, with particular attention to the temporal-spatial trends at the county and water watershed level. The relevant procedures consisted of two stages, as described below.

2.2.1 Stage 1: Identification of Variables, Data Gathering and Study Design

The first step involves the identification of the variables needed to assess the state of the environment in areas adjacent to coal mining fields as well as pollution trends along the counties, watersheds and streams of the state. The variables consist of environmental data such as land based elements (of the number of mining sites, number of watersheds,

156 impaired water bodies, categories of pollutants made up of biological elements, PH, and
 157 metals) and percentages of pollutants, coal tonnage, amount shipped, amount consumed,
 158 land, acres of mountain top clearance, location of species richness, degraded habitats
 159 and land, number of human casualties from mining hazards. In addition to the design stage,
 160 access to databases and abstracts that are presently available within the Federal and state
 161 archives in the state of West Virginia and the USGS, NASA, and host of other entities
 162 quickened the search process.

163 The appropriate variables were derived from additional sources such as government
 164 documents, newsletters and others (See Tables 1-4). The process continued with the design
 165 of data matrices for socio-economic and land use (environmental) variables covering the
 166 periods from 1980, 1996 to 2010., 1950 and 1976, 1969 and 2009 to 2012. The design of
 167 spatial data for the GIS analysis required the delineation of county and watershed boundary
 168 lines as well as species rich sensitive habitats within the study area as well. Given that the
 169 official boundary lines between the counties remained the same, a common geographic
 170 identifier code was assigned to each of the units to ensure analytical coherency.

171 2.2.2.1 Stage 2: Step 2: Data Analysis

172 In the second stage, descriptive statistics and spatial analysis were employed to transform
 173 the original socioeconomic and land-use data into relative measures (percentages, ratios
 174 and rates). This process generated the parameters for establishing, the extent of
 175 degradation and impacts such as change on the landscape, land loss and disturbance in
 176 the areas of the state devoted to coal mining along the counties. This was facilitated by
 177 measurements and comparisons of the trends in the area over time. While this approach
 178 allows for the detection of change. The tables highlight stressors, indicators of degradation
 179 and impacts, coal tonnage, tonnage shipped, tonnage used internally and the number of
 180 deaths. The matrix contains also acreages of mountain top clearance and other land use
 181 types attributed to the coal development activity which prompted the loss of open space and
 182 farm land loss in the state.

183 2.2.2.2 Step 3: Geospatial Data Processing and GIS Mapping

184 The remaining steps involve spatial analysis and output (maps-tables-text) covering the
 185 study period, using ARCVIEW. While the spatial units of analysis consisted of the coal
 186 mining counties of the state of west virginia and their watersheds. The geographic data
 187 assemblage for West Virginia which covered its watersheds and counties, also includes
 188 pollution and ecological data of land cover files of wetlands, watersheds, paper and digital
 189 maps from 1996, 1998, 2002, 2004 as well as NASA Satellite photo images dating back to
 190 1984 to 2012. In keeping with the aim of the paper, these Satellite images are only for an
 191 abbreviated analysis of the Hobet 21 mines in the study area. There is no attempt here to
 192 describe the processing of the photo images since it is beyond the scope of this study. The
 193 other aspects of the spatial analysis also center around the multi-temporal spatial data
 194 processing involving raw data sets of shape files, images, and maps obtained for the study.
 195 The outputs were mapped and visually compared with the trends evidenced in the area to
 196 see the extent of spatial dispersion of stressors associated with mining impacts, sensitive
 197 habitats, and the socio-economic factors fuelling change along the counties and West
 198 Virginia's watershed and its environment. This process helped show the evolution and
 199 spatial patterns of the stress induced by mining activities and other indicators across time.

200 3. RESULTS AND DISCUSSIONS

201
 202 This section of the paper presents the results and discussion of the various data analysis.
 203 There is an initial focus on the environmental analysis of coal use, land use change and the

percentages of change. This is followed by the impact analysis of water pollution hazards and spatial analysis of selected elements of degradation in the study area.

3.1 Environmental Analysis of Coal Mining Usage and Change 1996 to 2010

For the purpose of analysis, the temporal profile of coal use is provided herein. This is based on a breakdown of coal production, the tonnage distributed and consumed locally and the rates of declines over the years. In looking at the table, one notices that the total tonnage of all three categories from production to used tonnage declined in west virginia from 1996 through 2010. During the opening years of 1996 through the ten year stint of 2006, the state saw its quantity of coal production, the amount distributed and the tonnages consumed move from 174,008,217 tones, 172,762,769, and 356,852 to 158,835,504, 147,719,307, and 342,1054. This represents a change of 75, 87, to 54 percentage points respectively. From the period of 2008 through 2010, note that the production of coal in west virginia dropped from its 1996 levels to 162,750,817, 154,753,525 and 984,673 for the individual years (Tables 2.0 - 2.1).

Another important point worthy of note in 2010 touches on the recurrent drops in coal production, the amount distributed and those consumed internally in west virginia. During the 2010 period, the declines in the tonnages of coal produced, distributed and consumed went from 142,944, 106,122, 880,676, to 886,867. Notwithstanding the fact that the state's production levels and export totals of 180,794,012, to 169,918,795 in 1998 exceeded the other years, the people of west virginia only used 22,460 tons of coal, representing the lowest in the entire periods under analysis. This compares very low to the 2002 fiscal year when local use reached its highest levels of 12,503,110 tones. Having said that, local demand did fluctuate regularly in the state of west virginia (Tables 2.0 - 2.1).

Table 2.0 Coal Production and Distribution

Coal Production In tons 1996			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	164,024	Rail	95,268,867
Conventional	1,165,565	River	26,267,894
Continuous	77,926,024	Truck	50,869,156
Longwall	39,826,516	Used Locally	356,852
Total Underground	119,082,129	Total Distributed	172,762,769
Total Surface	54,926,088	NA	NA
Total Tonnage	174,008,217	NA	NA
Coal Production In tons 1998			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	914,600	Rail	104,122,424
Conventional	1,004,496	River	21,591,876
Continuous	76,954,561	Truck	44,297,423
Longwall	47,123,931	Used Locally	22,460
Total Underground	125,997,588	Total Distributed	169,918,795
Total Surface	54,796,424	NA	NA
Total Tonnage	180,794,012	NA	NA
Coal Production In tons 2000			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Other	79,700	Rail	88,527,001

Conventional	451,140	River	20,010,833
Continuous	68,039,484	Truck	46,946,811
Longwall	40,824,822	Used Locally	399,034
Total Underground	109,395,146	Total Distributed	155,902,023
Total Surface	59,975,456	NA	NA
Total Tonnage	169,370,602	NA	NA
Coal Production In Tons 2002			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	447,199	Rail	93,090,150
Conventional	437,748	River	14,053,979
Continuous	61,442,619	Truck	32,287,844
Longwall	38,272,692	Used Locally	12,503,110
Total Underground	100,600,258	Total Distributed	153,597,899
Total Surface	63,296,632	NA	NA
Total Tonnage	163,896,890	NA	NA
Coal Production In Tons 2004			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	NA	Rail	89,029,932
Conventional	1,165,269	River	16,925,192
Continuous	52,262,935	Truck	28,308,083
Longwall	42,639,402	Belt	6,975,188
Total Underground	96,070,784	Used Locally	5,936,098
Total Surface	55,612,689	Total Distributed	146,648,726
Total Tonnage	151,683,473	NA	NA

230
231

Table 2.1 Coal Production			
Coal Production In tons 2006			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	NA	Rail	87,941,361
Conventional	NA	River	17,233,499
Continuous	54,392,437	Truck	33,655,054
Longwall	37,518,001	Belt	8,424,616
Total Underground	91,988,281	Used Locally	3,421,054
Total Surface	66,847,303	Total Distributed	147,719,307
Total Tonnage	158,835,584	NA	NA
Coal Production In tons 2008			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	NA	Rail	97,789,053
Conventional	NA	River	16,167,452
Continuous	59,262,610	Truck	34,545,859
Longwall	37,851,475	Belt	5,493,243
Total Underground	97,378,703	Used Locally	984,673
Total Surface	68,372,114	Total Distributed	154,753,525
Total Tonnage	162,750,817	NA	NA
Coal Production In tons 2009			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total

			Tonnage
Auger	NA	Rail	81,765,180
Conventional	NA	River	15,749,307
Continuous	54,140,947	Truck	28,216,116
Longwall	33,222,745	Belt	4,221,693
Total Underground	87,366,423	Used Locally	1,025,080
Total Surface	56,651,335	Total Distributed	130,332,049
Total Tonnage	144,017,758	NA	NA
Coal Production In Tons 2010			
Production		Distribution and Use	
Method of Production	Total Tonnage	Method of Shipment	Total Tonnage
Auger	NA	Rail	74,813,353
Conventional	NA	River	16,197,386
Continuous	53,285,751	Truck	28,851,240
Longwall	38,909,548	Belt	3,977,807
Total Underground	92,235,636	Used Locally	886,867
Total Surface	50,708,470	Total Distributed	122,880,676
Total Tonnage	142,944,106	NA	NA

232
233

Table 2.2 Summary of Coal Production and Distribution

Year	Coal Production and Usage In West Virginia 1996-2010		
	Tonal Tonnage	Total tonage shipped	Total used locally
1996	174,008,217	172,762,769	356,852
1998	180,794,012	169,918,795	22,460
2000	169,370,602	155,902,023	399,034
2002	163,896,890	153,597,899	12,503,110
2004	151,683,473	146,648,726	5,936,098
2006	158,835,504	147,719,307	3,421,054
2008	162,750,817	154,753,525	984,673
2009	144,017,758	130,332,049	1,025,080
2010	142,944,106	122,880,676	886,867

234
235
236

3.2.1 Land Use Impacts From Mining

To understand ways in which mounting top removal mining has impacted West Virginia's environment, consider the available land use statistics from the periods of 1950, 1976 and the 2002 period. The temporal distribution of land use trend covers five different land types: developed, agricultural, open space, forest land area and disturbed areas with some mining. While the table highlights changes that occurred across time, it is clear that land slated for development in the 1950 period, grew from 42,533 acres to 135,566 in 1976 until it climbed further to 154,966 acres in 2002. From the data, open farmland acreage in the area fell from the all-time high of 950,135 acres in 1950 to 188,363 in 1976 and 246,082 in 2002. During this period, forest acreages in West Virginia's mountain top removal region jumped from 3,873,619 to 4,450, 580 only to drop by 4,284,141. Note also that the size of disturbed land areas grew from the initial tallies of 3,015 acres to 85,598 and 73,502 in 2002 (Table 3.0).

248
249
250
251
252
253
254

On the percentages of change, developed land grew by double digits with an exception in 1976-2002 when it stood at 14.3%. In the other periods, farmland and open space dropped by 80.5 to 74.1% but only to grow by 30.6% in 1976-2002. While forest area showed signs of identical gains of 14.8 to 10.5%, there was a notable decline of 3.7.3%. This was followed by significant growth rates in quadruple digits for disturbed areas most of the time (Table 3.1). Regarding the actual land use changes, during the periods of 1950-1976, 1976- 2002,

1950 –2002, the changes in the size of developed land stood at 93,033, 19,400, and 112,433 acres respectively. At the same time, agricultural land loss stood at -761,772 acres, and continued with a gain of 57,719 and further declines estimated at -704,053 acres. In all those years, the mountain top removal coal region posted slight increases (of 576,961, 410,522 acres) followed by losses totalling -166,439 acres. The disturbed land areas which were initially valued at 84,583 acres in 1950 -1976, fell to -12,096 in 1976 –2002. Between 1950 to 2002, the size of disturbed land areas climbed to 70,487 acres (Table 3.1).

Table 3.0 Summary Land Use Statistics For West Virginia Mountain Top Region

Land Use	Area (acres)			Percentage Changes		
	1950	1976	2002	1950-1976	1976-2002	1950-2002
Developed	42,533	135,566	154,966	218	14.3	264
Agricultural/ Open	950,135	188,363	246,082	-80.5	30.6	-74.1
Forest	3,873,619	4,450,580	4,284,141	14.8	-3.73	10.5
Disturbed (some mining)	3,015	85,598	73,502	2739	-14.1	2337

Table 3.1 The Land Use Changes In West Virginia

Land Use Changes	Area (acres)		
	1950-1976	1976- 2002	1950-2002
Developed	93,033	19,400	112,433
Agricultural Open	-761,772	57,719	-704,053
Forest	576,961	-166,439	410,522
Disturbed (some mining)	82,583	-12,096	70,487

3.2.2. Mountain Top Removal Mining and Impacts

The impact of mountain top removal among the four coal producing states in the Appalachian region adds another dimension to the analysis herein. The table containing three ecological indicators of size, number of mountains impacted and the percentages shows a troubling trend on the health of mountain top ecosystem and the threats to biodiversity found in the area. The total size of disturbed areas based on the table indicates Kentucky and West Virginia with 574,000 to 352,000 acres. While these numbers surpassed the 156,000 to 78,000 acres cleared in Virginia and Tennessee, it shows the first two states as the most active places in mountain top removal practice in the region. In the context of the study area, the entire region alone lost 1,160,000 acres covering about 501 mountains (Table 3.2). Of the overall acres of mountain tops removed, the states of West Virginia and Kentucky accounted for almost 80% percent combined compared to 20% for both Tennessee and Virginia. The interesting point to glean in the context of West Virginia is that the state ranks second in every category of ecological indicators of mountain top removal practices in the region.

Considering the externalities from mountain top removal, the risks to the adjoining ecosystems are devastating. There are problems with air pollution resulting from airborne movement of dusts, exposure to radioactive contaminants and geological residues. Additional dangers come from the cracking of natural areas providing life support essential for the survival of different species. The extensive clearance of mountain top habitats and forested areas trigger biodiversity loss and the disappearance of rare species of flora and fauna. It has been estimated that since 2003, about 1.2 million hectares of land were lost to mountain top removal (Appalachian Voices 2012c).

In the absence of trees in these circumstances to hold water and act as a barrier, it becomes very life threatening with flash flooding ravaging adjoining communities. One of the most

deadliest floods occurred in May 2009, in Mingo county and communities adjacent to south west Virginia coal mines (Appalachian Voices 2012b). Moreso, mountaintop mining waste holds chemical compounds usually found in coal and rock. In the process, rainwater falling on a valley fill becomes enriched with heavy metals such as lead, aluminum, chromium, manganese and selenium. Even when coal corporations design filtration pools to trap point source residues. Impure water from the slurry pools and metals that wound up downstream unavoidably, inflict further havoc by polluting aquatic environments. This ordeal is compounded further by the build up of abandoned mines and fragile impoundments containing toxic residues on mountaintop sites.

Table 3.2 The Distribution of Mountain Top Removal Acreage

Mountaintop removal mining impact study results by state				
Rank	State	Size	Number of Mountains Impacted	The Percentages
1	Kentucky	574,000 acres	293 mountains	49.51
2	West Virginia	352,000 acres	135 mountains	30.34
3	Virginia	156,000 acres	67 mountains	13.44
4	Tennessee	78,000 acres	6 mountains	6.72
Total		1,160,000 acres	501 mountains	100.00

Source:: Appalachain Voices 2012 c

3.2.3 The Pollution Impacts On The Watersheds

To understand the pollution trends among the watersheds, one needs to look at the totals, the number of mining sites, the main pollutants and the number of impaired streams over time from 1996-2004. With biological elements, Ph, and metals as the most common types of pollutants (Table 4). The frequency of their presence in the watersheds as indicated in the table are in the order of 9 for biological pollutants, 7 for Ph, and 4 for metals. Seeing that the total number of mining sites from which the pollutants originate stood at 65 during the periods of 1996, 1998, 2002 and 2004. The cases of impaired streams rose from the initial value of 1586, in 1996 to 2676 in 1998. In 2002, the numbers jumped further to 5389 and 4924 in 2004(Table 4).

The breakdown of the trends point to the presence of biological pollutants along the upper Monogahele watershed. Being the area with major mining sites estimated at 13, Monogahele watershed saw its number of impaired streams from biological pollutants which stood 56 in 1996 grow to 128 in 1998, and 182 in 2002 to 2004. At the same time, metallic pollutants remained quite rampant in four other watersheds most notably the Upper Kanwaha, Coal, Upper Guyandotte and Twelve pole. The estimated number of mining sites in these watersheds were in the order of 7, 11, 1 and 7 respectively. Along the Upper Kanwaha watershed, the number of impaired streams between 1996 -1998 grew from 250 to 319. In the later periods, it varied from 417 in 2002 to 402 in 2004. At coal watershed, the number of impaired streams attributed to metal sediments remained in high triple digits. This is evident between 2002 through 2004 and 1998, but only to drop to upper and lower double digits at Twelve pole watershed. The Upper Guyandotte watershed also experienced numerous cases of stream impairment. The number of cases were 242 in 1996, 328 in 1998, 427 in 2002 and 286 in 2004 (Table 4). See the Appendix A for more on watershed impairments.

3.2.3.1 Pollution Analysis

Another dimension to the analysis is that of the 21 watersheds in the study area, metallic elements from 26 mining sites are discharged into sensitive stream habitats (Table 4.1). As mentioned before, such practices have far reaching consequences on the surrounding ecosystem. From the table, these numbers represent about 40% of all mining activities in the

designated watersheds in the area. In terms of the percentage distribution of stream impairment reported in West Virginia, the four watersheds where metallic effluents are rampant accounted for 36.69% to 29.85% of impaired stream cases between 1996 through 1998. In the ensuing years, the percentage of impaired streams attributed to metals discharged from mining sites went from 30.61% in 2002 to 28.96% in 2004.

With metallic elements responsible for much of the stream pollution from 1996 through 2004. The overall number of cases which ranged from 1426, 1650, 799, and 582 as Table 4.1 shows impacted all watersheds. Considering that Coal, Upper Kanawha, and Upper Guyandotte emerged as the hotbeds of stream pollutions attributed to coal mining than the twelve pole watersheds. Their levels of toxicity are high enough to damage stream quality and habitats for marine organisms in such aquatic ecosystems. Aside from the analysis herein, iron and manganese concentration in water, exceeded drinking water standards in 40% of wells located in the Appalachian plateau and in nearly 70% of the wells adjacent to reclaimed surface mines of the region (Appalachian Voices 2012b). While nearby downstream water exhibits high conductivity levels, there were cases of hardness and selenium presence as well.

Table 4 Environmetal Pollution of Watersheds From Mining

Watershed	Mining sites Number	Pollutanat	Impaired streams 2004	Impaired streams 2002	Impaired streams 1998	Impaired streams 1996
Conococheque	1	Biological	226	226	30	0
Northbranch	2	Biological	109	115	98	53
South branch	1	PH	191	191	128	27
Lower Monogahele	2	Biological	146	146	37	36
Upper Monogahele	13	Biological	182	182	128	56
West fork	2	PH	333	375	284	258
Upper ohio-wheeling	2	PH	287	287	112	37
Little Musringum middle island	1	Biological	118	118	16	14
Little Kanawha	1	PH	303	308	235	66
Upper Ohio-shade	2	PH	287	287	112	37
Elk	3	Biological	358	383	199	96
Gauley	4	PH	162	200	141	112
Upper Kanawha	7	Metals	402	417	319	250
Coal	11	Metals	671	729	133	80
Twelve pole	1	Metals	67	77	19	10
Tug	3	Biological	222	307	184	148
Upper Guyandotte	7	Metals	286	427	328	242
Middle New	1	Biological	292	310	38	29
Lower new	1	PH	228	228	94	28
Lower Kanawha	1	Ph	67	89	65	33

352
353
354
355
356
357
358

Table 4.1 Comparative Pollution Aanalysis Metal Vs Other Pollutants

Watershed	Sites	Pollutant	Impaired stream 2004	Impaired stream 2002	Impaire stream 1998	Impaired stream 1996
Upper Kanawha	7	Metals	402	417	319	250

Coal	11	Metals	671	729	133	80
Twelve pole	1	Metals	67	77	19	10
Upper Guyandatte	7	Metals	286	427	328	242
Total	26	Metal pollutants	1426	1650	799	582
Overall Total	65	All pollutants	4924	5389	2676	1536
Total %	40	NA	28.96	30.61	29.85	36.69

3.2.4 The Human Hazzards of Minning 1980-2010

The human costs of mining is a recurrnt trend in west virgina. This can be buttresed from the data on Table 4.2. Since the 1980s to April of 2010, West Virginia's coal producing counties have been fraught with reccurent hazards attributed to mining. This has resulted in the death of about 61 people in different locations in the state during the periods under analysis. As incidents originating from coal producing companies, they involve gas explosions and other hazards which often lead to loss of lives. Aside from the single digit fatalities common in the decades of the 1980s, the 1990s and the early 2000s, the state experienced double digit casualties numbering 12 to 29 deaths between January the 2nd in 2006 to April the 5th of 2010. No matter the size of these accidents, they do impact the natural and built environment through emission of toxic chemicals coupled with the loss of human lives.

Table 4.2 The Hazzards From Mining In West Virginia 1980-

2010

Date	Company	Mine	Location	Nature of Accident	Nube of Victims
Nov. 07, 1980	Westmoreland Coal Co.	Ferrell	Uneeda	Gas Explosion	5
Dec 03, 1981	Elk River Sewell	Sill House No. 1	Bergoo	Roof Fall	3
Feb 06, 1986	Consolidation Co	Love ridge No. 22	Fairview	Coal storage entrapment .	5
Mar 19, 1992	Consolidation Co	Blacksville No. 1	Wana	Explosion in Shaft	4
Jan 22, 2003	Central Cambria Drilling	Mcelroy Mine	Graysville	Explosion in Shaft	3
Jan 2, 2006	Anker WV Minning CO	Sago Mine	Tallmansville	Explosion and Entrapment	12
Apr 5, 2010	Performance	Ubbmc Montcoal Eagle	Noama	Explosion	29
Total	Mining Accidents from Various Locations In West Virginia				61

Source: West Virginia Office of Miners Health, Saftey and Training, 2010

The incidence of environmental degradation from mining hazards and the threats to watersheds do not operate in a vacuum. They emanate from socio-economic and political elements and policy defects coupled with cozy industry and government relations and demographic elements of income groups and population. This section identifies the factors fuelling environmental degradation as a result of coal mining activities (See Appendix B). Notwithstanding the problems of environmental degradation emanating from the coal mining in West Virginia, there are concerted efforts to minimize the impacts. Those initiatives ranging from the mobilization of environmental groups to land reclamation efforts are described briefly in Appendix C. For more on the factors and the efforts among different entities see sub sections 3.3-3.4 in Appendix B and C.

3.5 The Spatial Analysis

To understand the impacts of mining on the ecosystem especially water bodies in west virgina, we must consider the presence of mining sites in space along watersheds and

streams in the adjoining areas. These features on the maps can be distinguished from the colors of red denoting mining sites and dark blue highlighting watersheds and the light blue for streams. While they offer essential services to the different life forms, they function as habitats and life support hubs to both humans and the natural environment. However, they are at risk from the menace of mining activities in the state. Just as the mining sites presented in red dots appeared sparsely distributed in space and evenly concentrated in some, their presence from the far north to the southern part and the proximity to the surrounding streams and watersheds in the state puts water quality and the different life forms using them as habitats at risk (Figure 2.0).

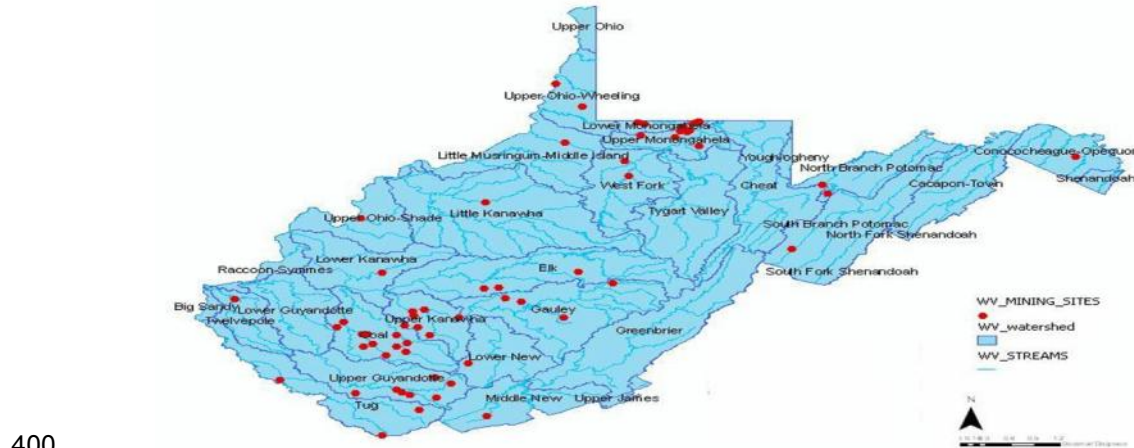


Fig. 2.0 The Spatial Locations of West Virginia's Mining Sites

From the geographic distribution of the mine sites in Figure 2.0, it is evident they are visible in the Northern and southern slope of the state. The presence of more mines alongside sensitive water bodies imply considerable risks to stream ecology than the areas where mining activities are less diffused. This comes with the growing concentration of mining by-products including heavy metals and others in the surrounding head waters of the state.

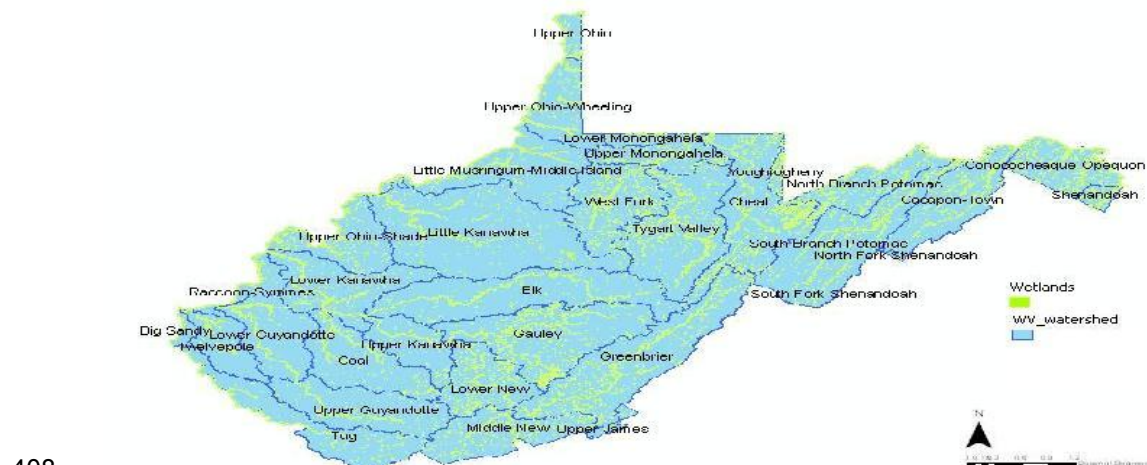


Fig. 2.1 Spatial Distribution of Wetlands In The State of West Virginia and Their Vulnerability

Knowing the dynamic nature of runoffs from pollution sources and the pace at which coal related pollution occur in the mining counties of west virginia, the study area experienced a slightly robust dispersion of impaired streams in 1998. With stream impairment apparent in areas where they were known to occur in the previous period of 1996, it is clear, degradation picked up more steam and extended into areas where they did not occur previously. This raises questions about the effectiveness of policy and clean up efforts in the area. As a new entrant, little Kanawha saw its share of areas under the threats of impairment stretched deeper into its adjoining boundaries. The same can be said of others like upper kanawha and those in the northern areas including upper ohio, upper wheeling and shenandoah and host of other areas where the head waters and streams experienced degradation from coal mining (Figure 2.3).

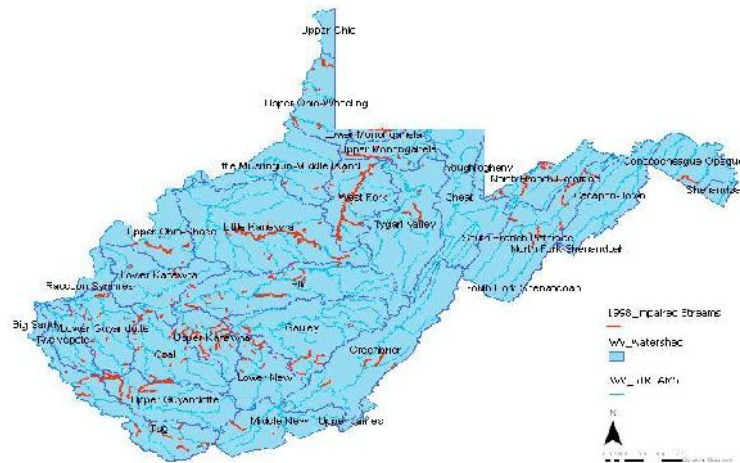


Fig 2.3 Impaired Streams In West Virginia In 1998

As we move towards the 2002 period, there began to emerge a slightly different kind of spatial patterns on the geographic diffusion of stream impairment linked to coal mining activities in the various areas (Figure 2.4). The frequency of these patterns, did have profound effects on stream quality in the affected areas.

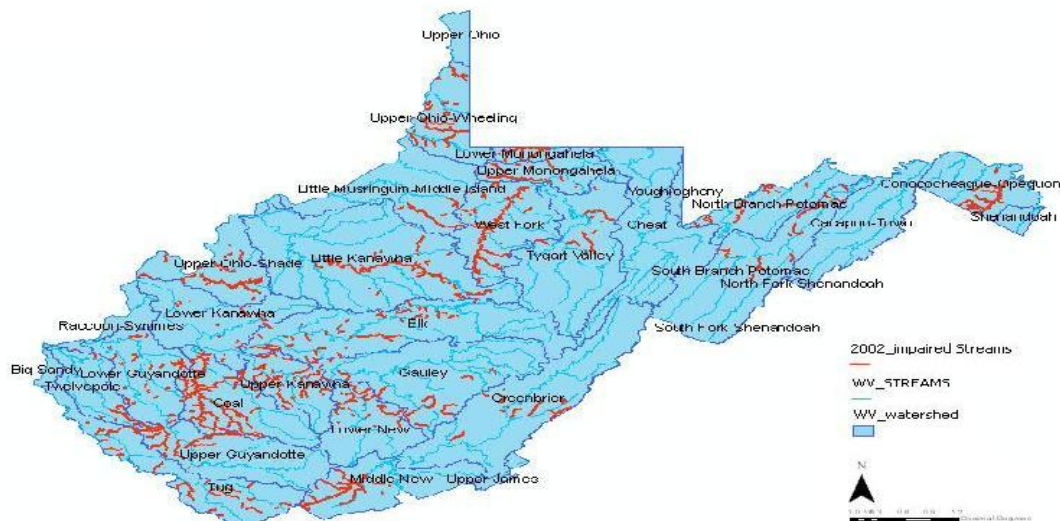


Fig. 2.4 Impaired Streams In West Virginia's Watersheds In 2002

The 2002 map offers extra evidence on spatial patterns of stream impairment. From the map, there are four major clusters of streams with notable cases of impairment from mining. The waterbodies in question are in the high section of upper Ohio, the north east shenandoah and the adjoining streams and watersheds. Consider also the upper north central streams of west fork, little Kanawha and the upper Ohio shade and elk in that category. Stepping onto the lower and deep southern tip of the map, note the gradual manifestation of heightened impairment cases in the lower Guyandotte, coal, and Tug, Greenbrie, Middle new, and the twelvepole streams. The major thing worth noting from the emergent spatial patterns

stems from the presence of impairment cases in areas prone to pollution in the study area at levels higher than the 1996 period (Figure 2.4).

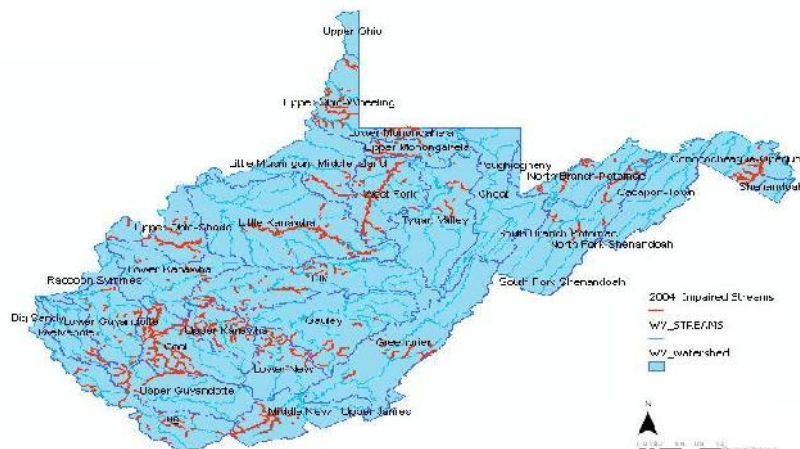
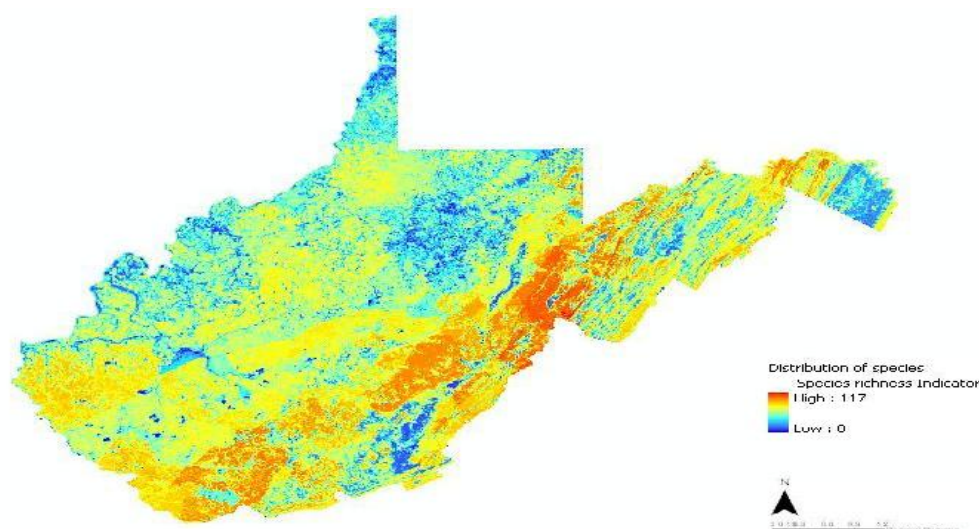


Fig. 2.5 Impaired Streams In West Virginia In 2004

The details in figure 2.5 outlines the spatial dispersion of impaired streams in west virginia. Despite some convergence in the geographic patterns of degraded streams in 2002 and 2004, there are slight differences in the dispersion of impaired streams'locations in the study area. The minor divergence in patterns is evident in the lower south and central tip of the map along Tug and Tygot valley. With impaired streams seemingly visible on many spots in a way similar to the previous period of 2002, a common trend in 2004 stems from the gradual fade away of degraded spots in the two areas under a much different pattern from the previous year. While it is clear that impaired streams were visible in space in 2004, one need not forget that most run-offs from mining sites empty into fragile streams and watersheds of the state. In that setting, the links between impairment and coal mining should not be overlooked (Figure 2.5).

In sum, there seem to be a large scale stream impairment along the surrounding ecology of fragile watersheds adjacent to mining sites in the state between 1996 to 2004. Comparing the 1996 and 1998 maps, one notices the slight diffusion of impaired elements into adjoining water systems in a manner not seen in the ensuing periods. Water impairment as a recurrent trend in the state assumed a much bigger scale as the years went by. During 2002-2004, large scale levels of degradation appeared extensively in the state. Within this period, the extent of pollution known to threaten streams reached enormous proportions in the lower and upper part of the state. The gravity of these impairments,continue to threaten the quality of watersheds in the state.

Regarding the vulnerability of biodiversity, Figure 2.6 shows the distribution of habitats for diverse species in various areas of the state where mining activities are quite active. The data represents also the circulation and conservation status of biodiversity in the state. These areas contain different life forms made up of butterflies, amphibians, reptiles, birds and mammals. The recurrence of poor environmental and safety management practices during mining activities not only pose enormous threats to ecosystem health in these areas, but sensitive habitats for different life forms are also vulnerable. The species richness index calibrated at high and medium scales of red and yellow colors maintained a large presence in different areas that are adjacent to mining activities.



495

496 **Fig. 2.6 Spatial Distribution of Species Richness Threatened By Mining Activities**

497 Taking into consideration such practices as mountain top removal and surface mining and the
 498 risks posed by abandoned mines and underground mine fires. It is evident that species
 499 richness spread across different areas of the state on the map remained at risk all these
 500 years. To analyse their significance and risks from coal mining, consider the scales on the
 501 map distinguished in multiple colors of red and yellow and light green as the highest
 502 locations of species diversity and the blue as the lowest points containing biodiversity. With
 503 all three thresholds for assessing the highest forms of species richness prominently
 504 dispersed across space. The spreading of thick reddish spots across the North east of the
 505 state adjacent to mining sites, abandoned mine lands and mountain top removal activities
 506 do heighten the vulnerability of biodiversity to hazards.

507 **3.6 Analysis of Green Space Degradation from Mountain Top Removal**

508

509 Another evidence of degradation stems from the spatial dispersion of mountain top mining
 510 impacts in Hobet 21 mine sites in West Virginia. Assessing these impacts required analysis
 511 of the geographic patterns of environmental degradation using multi temporal raw LANDSAT
 512 Satellite data images dating back to 1984, 1992 and 2012 on Hobet -21 mountain top mines
 513 along the mud River Watershed. The features on the maps symbolized by green and milky
 514 white colors represent indicators and stressors on the mountain top ecosystem. The green
 515 depicts open space in a mountain ecosystem, coupled with pipelines carrying mining
 516 residues into the tributaries, disturbed and restored areas along with mining operations.

517

518 A close analysis of the images show the progression of the Hobet - 21 Mountain top mine
 519 along the Mud river watershed of West Virginia (Figures 2.6-2.8). The images represent the
 520 expansion of the Hobet mine during the periods of 1984-2012. The usual background of the
 521 area showed shadowy green forested mountain wrinkled by tributaries and basins. At that
 522 time, the mountain features looked rancid-white, while areas under restoration with
 523 vegetation were delineated by bright green colors. Initially in 1984, one notices partial
 524 presence of mining operations in a fairly minor part along the western portion of the coal
 525 river with more stretches along the south west of the mountain top (Figure 2.6). In the 1992
 526 period, mining activity extended onto the north side with vast presence of debris deposits or
 527 rocks evident with valley fills and earth dams. This is apparent with the flattening of the
 528 landscape and the development of mining areas in the northwest (Figure 2.7). While the

529 area experienced the gradual emergence of green spaces and a reclaimed landscape in
 530 2012, the images still point to the proliferation of mining activities in both the South west and
 531 northwest (Figure 2.8). Consequently, in close to three decades (28years) of intense
 532 mountain top activities, landscape disturbance in the area not only grew, but it impacted over
 533 10,000 acres of land, the equivalent of about 15.6 square miles.

534



535

536

Fig. 2.6 The Hobet Mine 21 In The Study Area, September 21 1984. Source: NASA



537

538

Fig 2.7 The Hobet 21 Mine In The Study area 1992 August 2006, Source: NASA



Fig. 2.8 The Hobet 21 Mine In The Study Area September 20, 2012. Source: NASA

3.7 DISCUSSIONS

From the analysis, the state of West Virginia is so heavily dependent on coal mining activities, that the sector provides jobs, income and tax revenues for the state. This is evident from the monetary contributions of the coal industry to the state. The environmental analysis of the trends showed that aside from the benefits of coal over the years, coal production in the state has been fluctuating with visible decline between 1998 through 2012. The drawback rests on the fact that much of the coal produced in the state of west virginia are not all consumed there. While coal shipments often ended up at destinations in the surrounding states for various uses. It is worth stating that coal export and production in 1998 exceded the other years when local consumption stood at only 22,460 tons. In the process, west virginia not only carries the environmental burden of coal consumers outside the state, but it serves as a shadow ecology of those states at the expense of its own citizens who repeatedly choke from the externalities.

Accordingly, the production of coal are not without impacts especially in the area of land use. From the analysis, the size of developed land in 1950 rose from 42,533 acres to 135,566 in 1976. In the same period, the state saw its open farmland in mountain top coal producing areas drop to 188,303 in 1976. Within the same period, disturbed land areas rose from an initial tally of 3,015 to 85,598 untill it reached 73,502 in 2002. Sizable acres of land were also consumed due to coal related activities over the years. Infact agricultural land loss went from 112,433 in 1950 to -716,000 over the years. The danger is that land disturbance of this nature impedes the welfare of inhabitants. It leads to environmental degradation and loss of income from agriculture for those who depend on it and the state in general. The implication is that it amounts to deprivaion of livelihood and ecosytem disturbance. This is clearly unsustainable for the present generation and posterity. In a state where the human toll of mining hazards has been a reccurent trend in west virginia since 1998 to 2010. Mining hazards resuted in the death of over 60 innocent people in different sites in the state. With hazards ranging from explosions, entrapment, and gas explossions, roof fall and collapse, West virginians who regularly endured poor safety standards paid with their precious lives. This happens in a setting devoid of serious regulatory oversights and accountability.

Notable threats from mining consists of ecosystem damage during mountain top removal. As the paper showed, the state of west virginia saw 352,000 acres of its mountain top land varnish from mining. This occurred on about 135 mountains representing 30.36% of the mountain top excosytems in the Appalachian region. The problems of sediments, mud flow

574 and run-offs from such unsustainable practices do impede mountain ecosystems known for
575 their abundance in biodiversity and proximity to streams.

576 There are also growing impairment of streams and watersheds attributed to different
577 stressors from mining. While the analysis shows the presence of biological contaminants,
578 pH, and metals in streams and watersheds over the years in the study area. There exists a
579 vast load of biological pollutants along the upper Monogahele watershed. Over the years,
580 Monogahele watershed saw its number of impaired streams from biological pollutants jump
581 from 56 in 1996 to 128 in 1998 and continued at 182 cases in 2002 to 2004. Moreso, the
582 quality of four other watersheds in the state most notably the Upper Kanawha, Coal,
583 Upper Guyandotte and Twelve pole remained threatened from traces of metallic pollutants.
584 The number of impaired streams linked to metal sediments reached high triple digits during
585 1998,2002 through 2004. Just as the temporal-spatial analysis of watershed pollution in
586 West Virginia revealed large concentration of ecosystem inhibitors. Photo images and spatial
587 analysis of the impacts of mountain top removals between 1984-2012, not only showed a
588 vast presence of landscape disturbance in space, but degradation grew ver the years.
589 This resulted in extensive disappearance of open space with visible damage to the mountain
590 ecosystem.

591 The impacts of mining on waterbodies and wetlands were quite evident considering the
592 vicinity and risks to streams in various areas of the state. Considering the vast presence of
593 wetlands in areas known for recurrent degradation, the GIS analysis identified the enormity
594 of risks to which wetland biodiversity, water quality and the vital functions of the waterbodies
595 were subject to. Aside from the scattered patches of impaired streams in 1996, they were
596 highly visible across space in 1998. In that year, impairment stood firm with a robust
597 presence which later extended into other areas. In 2002 -2004 period, when a shift in spatial
598 patterns emerged, it turned out different from the previous year as impaired clusters on the
599 map faded slightly in the state. Another thing that emerged from the GIS analysis is that
600 habitats of species richness were spread around areas prone to mining hazards.

601 4. CONCLUSIONS

602 This part of the paper focuses on the closure along with some future lines of actions through
603 recommendations. To address some of the concerns that were identified in the current
604 research, recommendations from education and research to policy reform emerged as part
605 of the remedies. See Appendix D for a detailed analysis of these recommendations.
606 Essentially, this paper has explored the environmental impacts of mining using GIS with a
607 major focus on West Virginia. The paper presented the issues along with a profile of the
608 study area and environmental analysis of the trends. The research also focused on the
609 factors of change and efforts to stem degradation. With intense mining and the growing
610 demands over the years, it is evident that coal production in West Virginia posted visible
611 declines with impacts on the surrounding ecology and areas known for mountain top removal
612 activities. To analyze these issues, the paper used a mix-scale method of temporal-spatial
613 analysis involving descriptive statistics, GIS mapping and images of the Hobet 21 mines
614 mountain top landscapes in West Virginia.

615
616 From the analysis, it is evident that West Virginia boasts of substantial deposits of coal in
617 different areas of the state. Since its discovery, coal continues to find widespread use with
618 growing impacts on the environment. Just like the other states in the Appalachian region of
619 the US, coal as a non renewable resource is found in large quantities in West Virginia with
620 economic benefits. It is used for numerous things including electricity generation, domestic
621 and industrial applications. With coal dependence stretched across areas the mid Atlantic
622 and the emerging economies in Asia. The prevailing methods of mining made up of surface,
623 underground, and mountain top clearing leave in their wake degraded ecosystem with risks

624 to the surrounding streams and headwaters of the state. Between 1998-2010, the human toll
625 of mining hazards resulted in the death of 60 people in different sites in the state.
626

627 Accordingly, environmental impacts of mining continue to be manifested in the state of West
628 Virginia with visible damages to different life forms across time and space. This is partly
629 attributed to socio-economic variables of population, rising demand and export of coal to
630 local and overseas markets, income disparity and the dependency on revenues. Other
631 elements fueling ecosystem degradation from coal mining consists of political factors, policy
632 defects and a favorable terrain to the coal industry. The degradation of the environment as
633 stated earlier resulted in the disappearance of forest cover and vegetation, habitat loss, land
634 loss, growing threats to biodiversity and wetlands and watersheds. There were also large
635 concentration of toxic metals and other elements from mining in the surface water of the
636 area. Notwithstanding the continual decline in the tonnage of coal over the years and the
637 linkages between some socio-economic elements and environmental degradation, combined
638 efforts among various entities to minimize degradation showed some promise. However,
639 those initiatives have not stemmed the tide of degradation from mining completely.
640 Compounding the matter is the absence of a comprehensive mix scale analysis of the state
641 of the West Virginia's environment from the impacts of mining using temporal spatial
642 analysis.
643

644 Of great importance is the mix-scale approach of descriptive statistics and GIS in
645 highlighting the severity of change induced by mining. In the geospatial analysis, the paper
646 shows that while mining offers various benefits to West Virginia, it continues to impact nature
647 with multiple cases of watershed impairment in greater concentration in different areas of the
648 state. There were large spatial concentration of biological effluents, Ph and metals in
649 ecologically sensitive streams and the watersheds. Using GIS in that setting to track
650 watershed impairment and the dispersion of pollutants, improves our knowledge of the scale
651 of ecosystem stress. This inturn provides a framework for protecting the health of
652 ecosystems at risk through mitigation measures. The usefulness of GIS in that circumstance
653 stems from its capacity in pinpointing across space the threats of degradation. To remedy
654 the problem, the paper offered some suggestions ranging from the need to formulate a
655 corporate code of ethics for the industry, the design of data infrastructure and the continuous
656 use of GIS to sustain environmental decision making in the state.

657 **ACKNOWLEDGEMENTS**

658 We would like to thank the founding Dean of the College of Public Service at Jackson State
659 University for approving a request for conference travel and participation and the various
660 government agencies for making environmental and geospatial data available for the
661 research.

662 **COMPETING INTERESTS**

663
664
665 Authors have declared that no competing interests exist.
666

667 **AUTHORS' CONTRIBUTIONS**

668
669 'Author A' designed the study, performed the statistical analysis, wrote the protocol, and
670 wrote the first draft of the manuscript. 'Author B' 'Author C' and 'Author D' managed the
671 analyses of the study. 'Author E' and 'Author F' managed the literature searches, Authors G'
672 and H assisted with library searches..... All authors read and approved the final
673 manuscript."

674
675

REFERENCES

- 676 Appalachian Voices 2012 a. Community Impacts of Mountain Top Removal, Boone, NC;
677 <http://appvoices.org/end-mountain-removal/community> retrieved 2/18/2013
678 Appalachian Voices 2012b .Ecological Impacts of Mountain Top Removal. Boone, NC
679 <http://appvoices.org/end-mountaintop-removal/ecology/> retrieved 2/18/2013
680 Appalachian Voices 2012c Mountain Top Removal 101. Boone, NC.
681 <http://appvoices.org/end-mountaintop-removal/mtr1001/> retrieved 2/18/2013
682 Bureau of Business and Economic Research, February 2010. The West Virginia Coal
683 Economy Coal West Virginia University, Center For economic
684 Biswass, S. 2002. Remote Sensing and GIS Based Approach For Watershed
685 Conservation. Journal of Survey Engineering 3:108-124
686 Chhotray, S. 2008. Mountain Top Removal: Effects On Human Health and The
687 Environment. [http://www.law.sc.edu/environmental/papers/200841/eas/chhotray](http://www.law.sc.edu/environmental/papers/200841/eas/chhotray.pdf) pdf.
688 retrieved 2/18/2013
689 Kwalie, M. 2005. Watershed Characteristics, and Fabrics. The Application of Remote
690 Sensing and Geographic Informations Systems. Lakes and Reservoirs Resource
691 Management. 10:85-92
692 Lindberg T. 2008. Cumulative Impacts of Mountain Top Mining On Appalachian Watershed.
693 PNAS Early Edition 1-6
694 McIlmoil Rory 2010 June 22. Coal and Renewables in Central Appalachia, The Impact of
695 Coal On The West Virginia State Budget , West Virginia Center for Budget and
696 Policy, Downstream strategies Morgantown WV
697 McQuaid, J. 2009 Science, Nature and Mining. Smithsonian Magazine , January..
698 <http://www.smithsonianmag.com/science-nature/mining-the-mountain.html> GssG41h
699 retrieved 2/18/2013
700 Merem E., Twumasi YA. 2008.. Using Spatial Information Technology as a Monitoring
701 Device In International Watershed Conservation Along The Senegal River Basin
702 of West Africa. International Journal of Environmental Health 5:464-476
703 Merem E.C. (2013 January). Geospatial assessment of the Impacts of changing agricultural
704 landscape in Louisiana. The Journal of Marine Science, 3,1.
705 Merem E.C., Twumasi Y.A. (2012 a). Geospatial analysis of the changing agricultural
706 landscape of northern Mississippi. In Proceedings of AEHS conference, San Diego
707 California, March 2012.
708 Merem, E.C., Twumasi Y.A. (2012 March b). Using GIS and climate risk information systems
709 to analyze the vulnerability of coastal counties in Louisiana and Mississippi.
710 Resources and Environment. 1,1-1-18.
711 Merem, E.C., Twumasi, Y.A (2012 c). Using GIS and climate risk information systems to
712 analyze the vulnerability of coastal areas in the South East. In Proceedings of The
713 University Florida Climate Change Conference, Orlando FL, May 2011.
714 Merem, E.C. (2011 December). Using geospatial information systems in analyzing
715 urbanization impacts on stream habitats in southern Mississippi Coastal Ecosystem.
716 Journal of Environmental Science and Engineering, 5,12,1624-1641.
717 Merem E.C (2011 May) Geospatial information analysis of land use impacts in Southern
718 Alabama". Journal of Environmental Monitoring and Restoration (JEMREST) 7,01-25.
719 Merem, E.C. Twumasi. Y.A. (2011 December). Relationships between climate parameters
720 and forest vegetation at and near Digya National Park, Ghana. The British Journal of
721 Environment and Climate Change, 1,4, 2011-2115
722 Merem, E.C., Twumasi, Y.A. (2005a). GIS applications in land management: the loss of high
723 quality land to land development in Central Mississippi from 1987-2002. The
724 International Journal of Environmental Research and Public Health, 2,2,234-244.
725 Merem, E.C., Twumasi, Y.A (2005 December b). "GIS based analysis of growth

726 management and environmental decline of Central Mississippi region. Geographic
 727 Information Sciences 11, 2.130- 137.

728 Merem, E.C., Twumasi, Y.A (2005 December c).“GIS Based Analysis of growth
 729 management and environmental decline of the Central Mississippi Region. Annals of
 730 GIS, 11,2, 01.130- 138.

731 Merem, E.C., Twumasi, Y.A (2006).GIS and remote sensing applications in the assessment
 732 of change within a coastal environment in the Niger Delta Region of Nigeria. The
 733 International Journal of Environmental Health and Public Health, 3, 1,98-106.

734 Merem, E.C. Y.A Twumasi, J. Wesley, C Richardson and B Robinson. (2011 June 23rd).
 735 The Applications of GIS in the Analysis of the Impacts of Human Activities on South
 736 Texas Watersheds *International Journal of Environmental Research and Public*
 737 *Health* 8(6), 2418-2446

738 Merem, E.C. and Y.A Twumasi. (2010 May). Using GIS In Environmental Management:
 739 Green Assessment of The Impacts of Petroleum Activities In The State of Texas.
 740 *The International Journal of Environmental Research and Public Health*, 7(5), 2101-
 741 2130

742 NASSA 2013 Controversy In The Appalachian ,NASA Goodland Space Center

743 O'Brien , L. 1992. Introducing Quantitative Geography; Measurement Methods and
 744 Generalized Linear Measurement. New York: NY, Routledge

745 O'Leary, S. 2011 July. Booms and Burst. The Impact of West Virginias Energy Economy.
 746 West Virginia Center On Budget and Policy West Virginia Center for Budget and
 747 Policy, Charleston WV

748 Ott, W. 1995. Environmental Statistics and Data Analysis, Ann Arbor, MI: Lewis Publishers

749 Prakash, AK. 2007. Deciding Alternative Land Use Options In a Watershed Using GIS.
 750 *Journal of Irrigation Drainage Engineering*. 133:162: 174

751 Repetto, R. 1989. Wasting Assets Natural Resources in National Accounts, World
 752 Resources Institute, DC; Washington.

753 Robison, G .1998, Methods and Techniques in Human Geography, Toronto, Ont: Jon Wiley
 754 and Sons.

755 Usery. E.J. 2004. Geophysical Data Resampling and Resolution Effects On Watershed
 756 Modelling: A Case study Using Agricultural Non-Point Source Pollution Model.
 757 *Journal of Geophysical*. 6:289-306

758 US Bureau of Economic Analysis (2000 February). Accounting For Sub-Soil Mineral
 759 Resources .Survey of Current Business 33-49

760 US Bureau of Census 2007. The Economic Census Profiles US National and Local
 761 Economies Every 5 Years; DC Washington ,

762 USEPA. 2011 07/21. News Room News Release : EPA Issues Final Guidelines to Protect
 763 Water Quality in Appalachian Communities From Impacts of Mountaintop Mining/
 764 Agency to Provide Flexibility While Protecting Environment and Public Health.
 765 <http://yosemite.epa.gov/opa/admpress.nsf/le5ab112/> retived 2/18/2013

766 USEPA. 2009 09/11 . News Room News Release: EPA Releases Preliminary Results For
 767 Surface Coal Mining Permit Reviews.
 768 <http://yosemite.epa.gov/opa/admpress.nsf/d0cf661852a9efb825/> retrieved
 769 2/18/2013

770 USEPA. 2009 09/11 News Room News Release From Headquarters. Obama Administration
 771 Takes Unprecedented Steps To Reduce Environmental Impacts of Mountaintop
 772 Coal Mining, Announces Interagency Plan to Implement Reforms.
 773 <http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92> ceceeac retrieved 2/18/2013

774 US EPA 2001. Environmental Assessment. The Effects of Mountain Top Mines and Valley
 775 Fills On Aquatic Ecosystems of The Central Appalachian Coalfields pp 1-
 776 <http://efpub.gov/ncea/cfm/recordisplay.cfm?deid> retrieved 2/18/2013

777 West Virginia Rivers Coalition 2013, stop it Mountain top Removal pp1-3.
 778 <http://www.wvrivers.org/issues/mountaintopremoval/mtrrevealed.html>. retrieved

779 [2/18/2013](http://www.wvrivers.org/issues/mountaintopremoval/mintopremoval.html)
 780 West Virginia Rivers Coalition 2013, stop it Mountain top Removal pp1-2.
 781 <http://www.wvrivers.org/issues/mountaintopremoval/mintopremoval.html>. retrieved
 782 [2/18/2013](http://www.wvrivers.org/issues/mountaintopremoval/mintopremoval.html)
 783 West Virginia Office of Miners Health, Safety and Training: 2012 West Virginia Coal Mining
 784 Facts. Annual Reports
 785 Wiscombe, W. 2013 Controversy In The Appalachia NASA Goodland Space Center
 786 Yan, S. 2010 March Friday2 . In West Virginia, A Battle Over Mountaintop Mining. Science
 787 and Space. Time. Retrieved 2/18/2013. [http://www.time.com](http://www.time.com/time/health/article/0,8599,1971709,00.html)
 788 [/time/health/article/0,8599,1971709,00.html](http://www.time.com/time/health/article/0,8599,1971709,00.html)
 789 Yuill, C. 2002 February Land Use Assessment, Mountain Top Assessment. Mountain Top
 790 Mining In West Virginia. Draft Report., Morgantown, WV: West Virginia University,
 791 Natural Resource Center; Davis College of Agriculture, Forestry and Consumer
 792 Studies,

793

794

795 **DEFINITIONS, ACRONYMS, ABBREVIATIONS**

796 MHST: The West Virginia office of Mines' Health, Safety and Training
 797 NASA: National Aeronautics and Space Administration
 798 USGS: United States Geological Services
 799 SMCRA: Surface Mining Control and Reclamation Act of 1997
 800 EPA: The Environmental Protection Agency
 801 US: The United States of America
 802 GIS: Geographic Information Systems
 803 MRT: Mountain Top Removal
 804

805 **APPENDIX A**

806 **3.2.3 Watershed Impairments**

807 The gravity of pollution hazards attributed to multiple mining sites should not stop us from
 808 looking at the second tier of sites classified under the 1to 2 cathegories. The interesting point
 809 is that the frequency of damages and the accumalated stressors in them over the years are
 810 relatively lethal enough to degrade the environment. Among the watersheds adjacent to 1 to
 811 2 mining sites, Conococheque, South Branch, West Fork and North Branch seem to stand
 812 out. Among this group of watersheds most notably Conococheque and North Branch,
 813 biological contaminants stood out as the core stressors with hundreds of cases of stream
 814 impairments numbering 226, 109, to 155 from 2002 through 2004. Looking at the other class
 815 of watersheds like Upper Ohio wheeling and Little Kanawha, Ph impairments were
 816 distributed over the periods of 1996,1998 and 2002-2004 with numbers totalling 37, 112, 287
 817 and 66, 235, 308 to 303 cases.

818 Of the other set of lower tier watersheds (Middle new, lower new, and Lower Kanawha) an
 819 interesting scenarrio emerges. At middle new watereshed, cases of biological impairment
 820 occurred in 29 to 38 streams between 1996 and 1998. The trend extended further into the
 821 2002-2004 periods with 310 to 296 water bodies classified as impaired. This was a bit similar
 822 to the Lower new watershed, already dealing with high Ph content reported in 28 to 94
 823 streams and additional cases numbering 228 between 1996 to 2004. At Lower Kanawha,
 824 stream degradation from coal mining stayed on the rise with 33 to 65 incidents from 1996-
 825 1998. The trend continued in 2002 to 2004 with more cases reported in 89 to 67 streams.

826 **APPENDIX: B**

827 **3.3 Factors Responsible For the Problems**

828

829 As mentioned earlier, the prevalence of ecological degradation from mining hazards and the
830 threats to watersheds do not operate in a vacuum. They are linked to socio-economic and
831 political elements and policy defects as well as demography. These factors are listed in
832 detail on the following paragraphs under different themes.

833

834 **3.3.1 Economic Factors**

835

836 West Virginia would not be in the current ecological morass without the lust for coal
837 products. The demand for mountaintop coal has grown the past years, prompted partly by
838 rising costs of fossil fuel and the demand for non-renewable extractive resources. This is
839 attributed to the essence of coal as the economic engine driving the daily lives of US citizens
840 and the emerging economies of China and India. Accordingly, the cost of coal products in
841 the mid Appalachian region in serving those needs has increased threefold above the 2006
842 levels. In taking advantage of such a turn around, Virginia-based Massey Energy, in charge
843 of several of Appalachia's mountaintop activities, is committed to coal exports to China.
844 Growing requests in this case lead to mountaintop removal which the mining sector views as
845 the most gainful method. In the state, mountaintop removal and other kinds of mining
846 represented 42% of coal mining in 2007, about 10% higher than the previous ten years. The
847 gains from global market access to coal export trigger environmental externalities that
848 disrupt communities, hence the linkages.

849 **3.3.2 Political Factors**

850

851 A closer look on what transpired during timeframe of the study, show ample disregard for
852 human lives and the surrounding ecology of the state by the coal mining operators. Coal
853 is intertwined with politics in West Virginia. Such inter-linkage is an indication of the power of
854 coal industry in the political economy of the state. For recurrent degradations from coal to
855 happen while elected officials looked the other way stems from the political and economic
856 influence of coal lobby. This reinforces the deep entrenchment of local politics into the
857 nature-economy interface debate in the state. Knowing the significance in that setting, it is a
858 political suicide for office holders or those aspiring to denounce safety violations or propose
859 stringent legislations to bring the sector into compliance with Federal environmental safety
860 regulations. West Virginia's political elite has been firm in its backing of the coal sector. This
861 mutual rapport is demonstrated yearly during the state's Coal Symposium, when elected
862 officials and the coal sector socialize. This is compounded by the official positions of the
863 state government and congressional delegates who prefer softer regulatory oversight to
864 accountability. In the absence of that support and its ban by the US EPA, mountaintop
865 removal might not be permissible.

866 **3.3.3 Policy Defects**

867

868 Stronger policies supported by the executive branch and the other regulatory agencies at the
869 state and federal level are crucial for the attainment of compliance in the mining sector.
870 Under a command and control mechanism imbedded in those rules and the "polluter pay"
871 sanctions that come with it, violators who pay hefty fines would not want to be repeat
872 offenders. However, in the case of West Virginia, the mining industry was offered a safe
873 haven in 2002 when the Bush administration amended the regulation central to mountaintop
874 mining waste in a ploy to circumvent the lawful prohibition on valley fills. Lately, the US
875 Interior Department with the US EPA approval, reversed regulations sanctioning mine waste

The prevailing socio-cultural setting and environment of West Virginia provides the ideal setting best suited for the mining industry. The state has the second to lowest GDP per capita and second lowest median household income. It also ranks 6th among states where citizens live below the poverty level (US Bureau of Census 2007). Seeing that the state of West Virginia ranks poorly in most socio-economic indicators that measure overall wellbeing among all states in the US, it comes as no surprise that only a small number of businesses with the exception of coal mining are attracted to mining towns lacking basic necessities where physical infrastructures in the built environments are under the worst conditions. In the absence of regular source of revenues to provide services to the needy communities, impoverished counties in these places turn to revenues generated from mountaintop removal as their only source. Mining operators who capitalize on these situations, exploit the economic conditions of those poor counties to their advantage at the expense of a clean environment for the citizens. With such a favorable terrain for the industry, it is hard to survive politically in mining counties where those who back it thrive through the ballot box by reaping huge rewards in campaign donations compared to their challengers.

In terms of other economic factors, the geography of over dependence on revenues from mining in a fiscally challenged state such as West Virginia should not be overlooked. This can be buttressed from the map in Figure 1.3 where just a few counties account for the largest concentration of income at a scale much higher than the rest of the state. Tougher regulations in those settings, could be interpreted as taking jobs away in economically depressed areas where citizens need jobs in the mining sector for their daily survival, hence the tendency in the state to soften regulations in favour of the mining industry.



911

Additional information from the map in figure 3 consists of three classes made up of yellow representing low percapita income of (10174-15000 and 15000-2000) in orange and the red symbolizing 20000-25000 group (Figure 1.3). The other thing to glean from the spatial distribution of per capita income is that being a less affluent state, there is a minor concentration of higher income brackets in a few areas of the state compared to the other cathegories in yellow and brown. Under that scenario in space, there is a always a predisposition to support mining activities at every cost in order to generate wealth no matter the consequeunces on the surrounding ecology of the area.

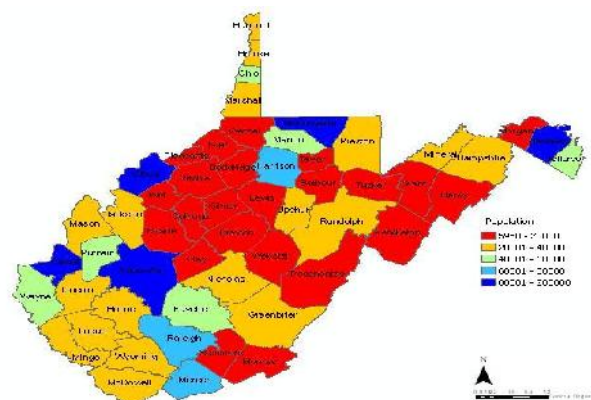


Fig. 1.4 showing total population in the WV counties Source: US Census.gov, 2006

3.3.6 The Spatial Distribution of Population

The geographic distribution of populations in west virginia from the map shows multiple classes of population concentration with the highest class identified as the blue and the medium ones in light blue and light green (Figure 1.4). This is followed by the low classes of population presence in orange and red. The problems associated with the spatial distribution of population in the face of mining impacts is that regardless of the location and the number of people around them, built environments are always at risk. This can be seen from the dangers posed by different aspects of coal mining from mountain top removal minning, surafce and underground mining and their proximity to the river systems around them. While high population zones are merely a collection of about 8 counties, the exposures to air and water pollution would be as damaging as the risks faced by low density counties represented in red and orange. The concern here centers on the vicinity of these communities to the mining sites of the state. Looking at the mining sites of the state and the adjacent streams, one notices their vicinity to built environments. Such proximity raises the level of risks to human lives and properties as well as the environment.

APPENDIX C

3.4 Efforts to Deal With the Problems

Within the study area, there are ongoing efforts to contain the environmental impacts of coal mining. Those initiatives ranging from the mobilization of environmental groups to land reclamation efforts are described briefly below.

3.4.1The Active Mobilization of Environmental Groups and Legal Actions

The growing incidence of ecological degradation from mining activities is prompting the mobilization of environmental groups in support of communities whose livelihoods and ecosystems were ravaged in the state. In the past years, the support involved capacity building, educational trainings and enlightenment campaigns as well as legal and financial assistance to sustain the aspirations of impacted communities. Many communities who benefited from such coalescence were acquainted with their rights under existing policies and legislations. Ever since the late 1990s, environmental NGOs and the residents of coalfield communities have initiated lawsuits against coal operators and regulatory agencies over these mines. The crux of their case not only center on the illegality of streams as a landfill for mining waste in accordance with the Clean Water Act, but their argument view valley fills as a contravention of the basic provisions of the 1977 Surface Mining Control and Reclamation Act which require mining operators to return sites to their pre-land use form in whichever way they are capable. Under this law, adjustments could be arranged should the mining company provide precise strategies for post-mining initiatives that would transform mined areas to amenities beneficial to the public like learning centers, homes or malls.

3.4.2 Federal Guidance On Mining

To deal with the problems associated with mining, the U.S. Environmental Protection Agency (EPA) has been active in the past few years in charting a new course towards effective monitoring. In the process, the agency put forward a definite path on Appalachian surface coal mining. This was aimed at arriving at a more reliable, operational, and judicious assessment of surface coal mining permits in accordance with the Clean Water Act and other laws. The proposed guideline draws heavily from the current advances in research, development and technology and it integrates public views and responses from over 60,000 remarks given by the participants. In furnishing EPA's local branches with the up-to-date data on the present legal standards, the regulation assists them to collaborate with states, the U.S. Army Corps of Engineers, mining companies, and citizens in arriving at an acceptable method that shields communities from hazardous contamination originating from coal mining. The expectation is that the EPA will enforce the regulations amenably, in line with the common experience of individual sites.

3.4.3 Growing Coordination among Federal Agencies

Recently the Obama Administration officials proclaimed they are taking unparalleled measures to diminish the impacts of mountaintop coal mining in the six Appalachian states including West Virginia under a synchronized model amongst the EPA, Department of the Interior (DOI) and Army Corps of Engineers. Building on a joint agreement reached between the respective agencies and the US Interior department, the Administration an implemented Interagency Action Plan focused on mountaintop coal mining to subside the negative ecological impacts through interim measures finalized in 2009. Other aspects of the plans involved long range initiatives to strengthen guidelines on mountaintop mining and collaborations among agencies with tougher environmental assessments and rigorous scrutiny of permit requests in keeping with the Clean Water Act (CWA) and the Surface Mining Control and Reclamation Act (SMCRA) of 1997.

3.4.4 Reclamation and Reforestation Initiatives Involving the Private Sector

Having seen the role of mining in fueling degradation in areas adjacent to the coal fields, elements in the industry have taken it upon themselves to restore and reclaim degraded ecosystems in counties affected by the horrors of mining in the state. Knowing the complex process involved in such task, coal entities are now active in restoring previously degraded mountain top sites. As a difficult initiative, it requires a decade and a half to implement. Examples of the process involve a combination of valley fills and new hilltops of crushed

998 rock covered with topsoil and crushed shale capable of holding tree roots when lightly filled.
 999 With much of the hills covered previously with vegetation's and different types of trees. Such
 1000 kind of recovery demands a high level of land management which numerous coalfield
 1001 entities are unable to offer. Consequently, the lasting ecological effects remain uncertain,
 1002 given the wave of stream degradation through valley fills and the sheer number of policy
 1003 obstacles out there to overcome.

1004 **APPENDIX D**

1005 **4.1 Recommendations**

1006 **4.1.1 Institute a Corporate Environmental Code of Ethics for the Mining Sector** 1007 4.1.1 Institute a Corporate Environmental Code of Ethics for the Mining Sector 1008

1009 There is a mutual relationship between humans and ecosystems, yet industry critics forget
 1010 that doing away with the ecosystem in any form under the pretext of development does more
 1011 harm than good to communities who face the daily ordeal of degradation. Seeing that in
 1012 West Virginia every decision made in the mining corporate board rooms of the sector
 1013 impacts the environment and the wellbeing of communities as this paper has shown, there is
 1014 an ethical obligation which must be addressed through strict adherence to a corporate code
 1015 of ethics by the sector. Because there is something intrinsically good about the people and
 1016 the different life forms that make up communities where mining activities occur, it is pertinent
 1017 that those values be observed by the industry. Consequently there is an urgent need for a
 1018 corporate body of norms and standards to hold the practices of the industry accountable for
 1019 good stewardship of the environment.
 1020

1021 **4.1.2 Subject the mining sector to Tougher Reviews** 1022 4.1.2 Subject the mining sector to Tougher Reviews

1023 The regulation of mountaintop coal mining practices need not be grounded solely on the
 1024 belief that the laws are always functional when crafted. In the case of water pollution from
 1025 mining, the scanty oversight of its ecological impacts may not always solve the problems.
 1026 Environmental policy without effective enforcement mechanisms like reviews not only risks
 1027 losing its appeal, but there is a danger of being branded out of touch with the very issue it
 1028 ought to be addressing. Rolling back laws in this circumstance diminishes the effectiveness
 1029 of federal regulators in addressing the ecological impacts of mining. Seeing the extent of
 1030 degradation in communities adjacent to West Virginia coal fields known for mountain top
 1031 removals, stringent assessments with standards will help ensure the quality of regional
 1032 waters and sensitive streams as stipulated in the Clean Water Act. This would make affected
 1033 areas regain their touch of livability even at the end of mining operations by bringing the
 1034 industry into compliance with the existing Laws.
 1035

1036 **4.1.3 Support Reforestation and Reclamation** 1037 4.1.3 Support Reforestation and Reclamation

1038 The need for reclamation of degraded landscape in the study area after many years of
 1039 mining is central to the ecological regeneration of communities known to have experienced
 1040 serious disturbance over time. This is important considering the gravity of accumulated
 1041 degradation and experience of communities located around West Virginia's coal fields. In
 1042 that setting, it is worth pointing out that the cessation of mining operations does not always
 1043 end ecological disturbance in affected areas. Even though the regulation requires a
 1044 mountain top removal site be restored and returned to its pre- land use form at the end of
 1045 activities, however most landscapes remain in ruins. Under that circumstance, reforestation
 1046 problems are barely given serious consideration. Knowing the abundance of biodiversity in
 1047 the study area with diverse species of flora and fauna, abandoned mines and habitats which
 1048 should have been reclaimed to ensure species richness are left to languish. In that light, the

1049 paper calls for the reforestation and reclamation of degraded areas in order to restore
1050 landscapes to their previous forms in affected counties.

1051

1052 **4.1.4 Improve Data Infrastructure and Design Regional Ecological Information System**

1053

1054 In the course of this study, there was no centralized data clearing house on the impacts of
1055 mining in west Virginia. In the process. available facts on mining impacts were scattered
1056 and disjointed in different places. To improve the situation, it is suggested that the
1057 authorities in the state of West Virginia improve existing environmental technologies and
1058 strengthen public access to data on degradation. This would enhance the ability to carry out
1059 impact assessment and reviews of coal fields activities in the state. There is also a need for
1060 more geospatial data on the impacts of mining on affected counties along west virginia's coal
1061 fields. Without access to a spatially referenced system, decision makers and mining
1062 operations would not know the location and severity of degradation in space and the
1063 dangers posed to the cosystem. This would sharpen the readiness of regulators in reviewing
1064 policy violations while ensuring compliance.

1065

1066

1067

1068

1069