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Investigating the Association of White Male Lung Cancer Mortality and State of Residence

Thomas Jeffrey Doker

ABSTRACT

THOMAS J. DOKER
Investigating the Association of White Male Lung Cancer Mortality and State of Residence
(Under the direction of MICHAEL P. ERIKSEN)

Lung cancer is the most common cause of cancer-related death. Most lung cancer is the result of a preventable cause, smoking. Nevertheless, U.S. tobacco production remains the fourth highest globally. This study examined the spatial aspects of U.S. White male lung cancer mortality and the associated risk factors of tobacco acreage, rural residence, smoking, poverty, lack of health insurance, and radon exposure. White male lung cancer mortality was significantly correlated with tobacco acreage (r = .455), rural residence (r = .389), and smoking (r = .475). Tobacco acreage (p = .005), rural residence (p = .011), and smoking (p = .030) remained significant with regression analysis. In qualitative analysis using a Geographic Information System, clustering was evident for all factors but only tobacco acreage correlated well spatially with White male lung cancer mortality. Tobacco-growing states were shown to have statistically higher lung cancer mortality 20 years later among White males. The causes for this mostly preventable cause of death need further investigation in order to target effective public health interventions.

INDEX WORDS: lung cancer, tobacco, rural, smoking, poverty, health insurance, radon

INVESTIGATING THE ASSOCIATION OF WHITE MALE LUNG CANCER

MORTALITY AND STATE OF RESIDENCE

by

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CHAPTER I

INTRODUCTION

1.1 Background

Lung cancer is the most common cause of death from cancer in the United States and accounts for 28% of all cancer deaths. In 2009, the American Cancer Society estimates that 159,390 people will die from lung cancer. This is three times more than from the second most common cause, colon cancer (49,920 deaths), and 23,560 more deaths than from all digestive system-related cancers (135,830 deaths) (American Cancer Society, 2009). Each year more men are diagnosed with lung cancer and have a 58% higher lung cancer mortality rate than women. Blacks are more likely to develop and die from lung cancer than those from any other racial or ethnic group (American Lung Association, 2008). However, White lung cancer mortality is decreasing annually at a slower rate than Black mortality and thus the rates are converging (National Cancer Institute, 2009).

When the young and middle-aged (≤ 70 years of age) were evaluated, smoking was by far the leading preventable cause of death in both men and women in the United States (Danaei, Ding, Dariush Mozaffarian, Rehm, Murray, & Ezzati, 2009). Fifty percent of those who continue to smoke will die from smoking-related diseases accounting for nearly 20% of deaths in the United States (American Cancer Society, 2009). Smoking contributes to 80% and 90% of lung cancer deaths in women and men, respectively. Compared to never-smokers, men who smoke are 23 times and women are 13 times more likely to develop lung cancer. The risk of lung cancer depends largely on the duration of smoking and the number of cigarettes smoked (U.S. Department of Health and Human Services, 2004).

In 2007, the United States was the fourth leading producer of tobacco leaf with 353,177 metric tons (Shafey, Eriksen, Ross, & Mackay, 2009). The location of U.S. tobacco production has changed little since the 1930s with most farms concentrated in Appalachia (Capehart, 2004). Forty-two percent of the Appalachian population is rural compared to 20% of the rest of the United States and 88% are White (Appalachian Regional Commission, 2009). Death rates for male lung cancer have been shown to be 25% higher in the Appalachian Region than in the rest of the United States. The higher rates of lung cancer in Appalachia are likely related to the high prevalence of adult smoking (Wingo, et al., 2008). Various authors have noted the cultural significance of tobacco within tobacco-growing areas. Often, tobacco is a primary cash crop which contributes an economic disincentive to the prevention and control of tobacco use (Meyer, Toborg, Denham, & Mande, 2008). Appalachia is associated with high rates of poverty and unemployment (Bagi, Reeder, & Calhoun, 2002). Factors associated with socioeconomic status contribute to substantial differences in lung cancer incidence and mortality (American Cancer Society, 2009).

1.2 Purpose of the Study

An association between lung cancer and smoking has been established. However, few studies to date have examined the spatial relationship between White male lung cancer mortality and tobacco cultivation. A finding that regional relationships affect lung cancer mortality would illustrate a greater requirement for national public health initiatives. Much of what is currently understood about regional influences on lung cancer mortality is focused on individual risk factors. More research is needed to understand regional risk factors independently and combined. Spatial analysis is important to making regional assessments as statistical analyses may not pick up clustering of geographic data.

1.3 Research Questions

The purpose of this study is to add to the existing body of literature linking White male lung cancer mortality and its associated risk factors. The associations were investigated by using the following research questions:

1. Do the states with the highest White male lung cancer mortality rates reflect regional influences?
2. Are White male lung cancer mortality rates associated with the tobacco acreage cultivated within the state of residence?
3. Are White male lung cancer mortality rates associated with state percentage rural population?

4. Are White male lung cancer mortality rates associated with state percentage adult current smoking from a year plausible with lung cancer lag time?
5. Are White male lung cancer mortality rates associated with state percentage poverty levels?
6. Are White male lung cancer mortality rates associated with the state percentage of those without health insurance?
7. As the most common non-smoking risk factor for lung cancer, is estimated state average radon exposure associated with White male lung cancer mortality.

1.4 Hypotheses

The demographics of lung cancer have changed over time and regional influences have been important. Displaying the data with mapping should allow quick and easy assessments of the various regional risk factors. Using current White male lung cancer mortality statistics, the states with tobacco-producing areas including parts of Appalachia (Alabama, Georgia, Kentucky, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia) should have higher rates than the rest of the United States. The pattern should also correspond with all the states which produced tobacco 20 years ago. This corresponds to when the "tobacco culture" would have influenced smoking prevalence associated with current lung cancer mortality. Higher smoking prevalence 13 years prior is hypothesized to correlate with higher White lung cancer mortality. Those states with higher percentage poverty and related higher lack of health insurance prevalence should have higher White male lung cancer mortality rates. Radon exposure should have only a minor impact on

White lung cancer mortality rates since only a small percentage of lung cancer mortality is attributable to radon exposure. In addition, radon exposure is based on geological and physical factors and thus may not correspond spatially with the major behavioral factor of smoking.

1.5 Delimitations

The study was limited to the 50 U.S. states and the District of Columbia (*n* = 51). Secondary data were available publicly at this level and a sufficient sample size was obtained. Study results cannot be generalized to other global locations, nor can they be generalized to the sub-state level. The most current data obtainable were used for White male lung cancer mortality, rural residence, poverty, and lack of health insurance. Only data from 1985 were used for tobacco acreage, and other years were not assessed. Using 1985 tobacco acreage provided a 20-year lag for the evaluation of 2005 lung cancer mortality, the most commonly mentioned lung cancer lag period from the literature review. Smoking prevalence data were limited by the date relevant data were initially collected at the state level; therefore, 1992 data were used. Associations with other years of adult current smoking were not calculated. This study looked at White male lung cancer mortality and did not assess mortality of other races and ethnicities or of females (a study of Black male lung cancer mortality and state of residence was added later: see Appendix A).

Only state-level lung cancer mortality, tobacco acreage, rural residence, smoking prevalence, poverty, lack of health insurance, and radon exposure were evaluated. Sub-state analysis was not done due to the difficulty of getting county-level or smaller data for all the covariates examined from publicly available sources. Also, using smaller areas can generate many null fields for health statistics due to privacy issues. State-level data is useful for delineating regional clusters and evaluating state tobacco policy influences. Regional data was not used due to needing a sufficient sample size for statistical analysis.

1.6 Limitations

This study relied on secondary data and thus was limited by the accuracy and quality of the data sources. Any inaccuracies in the data files impacted the study results.

1.7 Assumptions

The following assumptions were made:

1. The data were accurate and complete.
2. Historical data were relevant for predicting current lung cancer mortality.
3. Averaged state radon exposures were relevant for assessing lung cancer risk.

CHAPTER II

REVIEW OF LITERATURE

The purpose of this study was to investigate the association of White male lung cancer mortality rates and state of residence. The associated research questions included looking for regional differences in White male lung cancer mortality rates, tobacco acreage cultivation, rural residence, smoking, poverty, lack of health insurance, and radon exposure. A review of the literature was necessary to explore the epidemiology of lung cancer in the United States, the epidemiology of U.S. tobacco use, the demographics of U.S. tobacco agriculture, and the sociobehavioral risk factors of tobacco use in the United States. In addition, the review included an overview of nonsmoking risk factors of lung cancer, access to lung cancer healthcare, and prior geographic information system (GIS) lung cancer studies.

2.1 Epidemiology of Lung Cancer in the World

Lung cancer is the most common cancer diagnosed and the leading cause of cancer deaths in the world (Alberg, Ford, & Samet, 2007; Dubey & Powell, 2008). Lung cancer is more common in the developed countries than in the developing countries. However, while lung cancer trends are decreasing for developed countries, they are increasing in the developing world. In 2000, most lung cancer deaths occurred in

Western Europe and North America. The least number occurred in parts of Latin America and sub-Saharan Africa. Within most countries, male lung cancer incidence is double that of the incidence of women (Alberg, Ford, & Samet, 2007). The highest percentage of female lung cancer deaths were in North America (Ezzati, Henley, Lopez, & Thun, 2005).

2.1.1 Attributable Fraction of Lung Cancer due to Smoking

Cigarette smoking accounts for 90% of lung cancer cases in countries where smoking is common (Alberg, Ford, & Samet, 2007). Ten to fifteen percent of active smokers will develop lung cancer from cigarette smoking (Dubey & Powell, 2008). In 2000, an estimated 328,000 lung cancer deaths occurred in developing nations and 520,000 lung cancer deaths within industrialized nations (Ezzati, Henley, Lopez, & Thun, 2005).

Lung cancer was a rare disease in the 19th century, but it became the leading cause of preventable death in the 20th century (Cooley, Kaiser, Abrahm, & Giarelli, 2001). The introduction of manufactured cigarettes in the late 1800s led to the lung cancer pandemic in developed countries (Alberg, Ford, & Samet, 2007). In the developing countries, an increase in smoking prevalence has led to an increase in lung cancer mortality. Since smoking prevalence is higher in men, male lung cancer mortality exceeds that of females. The countries with the highest numbers of male smokers are China, India, Indonesia, the Russian Federation, and the United States (Shafey, Eriksen, Ross, & Mackay, 2009). In

India, the most common form of tobacco smoking is bidi smoking. Bidis are smaller than conventional cigarettes in that they contain less tobacco but they deliver higher amounts of nicotine per gram. Case-control studies have shown that bidi smoking causes lung cancer (Vineis, et al., 2004). Unfortunately, smoking prevalence is increasing in females and the gender gap in lung cancer mortality rates is closing. The United States leads all other nations in the number of female smokers (Shafey, Eriksen, Ross, & Mackay, 2009).

Nonsmokers exposed to environmental tobacco smoke (ETS) have a 20 to 30% increased risk of developing lung cancer (Shafey, Eriksen, Ross, & Mackay, 2009). ETS is composed of nearly 5000 identified chemical compounds with 43 meeting the criteria of a known carcinogen established by the International Agency for Research on Cancer (Brownson, Eriksen, Davis, & Warner, 1997). In 1986, the U.S. Surgeon General and the National Academy of Sciences concluded that ETS is a cause of lung cancer in nonsmokers (Brownson, Figgs, & Caisley, 2002). In 1992, the Environmental Protection Agency (EPA) estimated a relative risk of 1.19 (90% confidence interval: 1.04, 1.35) for lung cancer to develop in nonsmokers whose spouse smoked. The EPA further estimated that 3000 lung cancer deaths annually in the U.S. were attributable to ETS (Brownson, Eriksen, Davis, & Warner, 1997). In the European Union (EU), 13,241 lung cancer deaths were attributable to secondhand smoke in 2002 (Shafey, Eriksen, Ross, & Mackay, 2009).

2.1.2 Attributable Fraction of Lung Cancer due to Non-smoking Risk Factors

Radon: The EPA estimates that 15,000 to 20,000 lung cancer deaths yearly in the United States are due to radon exposure (Alberg, Ford, & Samet, 2007). In the United Kingdom (UK), around 1100 deaths from lung cancer are related to radon and represents 3.3% of all deaths from lung cancer. The mean radon concentration in all UK homes is 21 Bq/m^3 (0.57 pCi/L) which is less than the UK action level of 200 Bq/m^3 (5.4 pCi/L). The mean radon concentration of the EU is 55 Bq/m^3 (1.5 pCi/L). The EU lung cancer percentage attributable to radon is 8% of all lung cancer deaths or 18,000 deaths each year (Gray, Read, McGale, & Darby, 2009). Radon is a gaseous product in the decay series of uranium which can enter into buildings and homes (Barros-Dios, Barreiro, Ruano-Ravina, & Figueiras, 2002). Upon decay, radon releases α particles that can damage the DNA of cells in the respiratory tract. Cigarette smoking and radon act synergistically to cause lung cancer (Alberg, Ford, & Samet, 2007). About one in seven UK lung cancer deaths from radon are caused from radon exposure alone. The rest are caused by radon and smoking acting in a supra-additive manner. The radon dose-response relationship is likely to be linear since even low levels cause epithelial damage through α emission (Gray, Read, McGale, & Darby, 2009).

Occupational Exposures: Many occupational exposures have been studied for their relationship to lung cancer including radon exposure within uranium mines. Other exposures include benzopyrene in coke oven workers; arsenic, chromium, and nickel in welders and smelter workers; asbestos and beryllium in shipyard workers; pesticides in agricultural workers (Alavanja, et al., 2004); and diesel exhaust in truck drivers (Garshick, Laden, Hart, Rosner, Davis, & Eisen, 2008) and railroad workers (Laden, Hart, Eschenroeder, Smith, & Garshick, 2006). Cigarette smoking potentiates the carcinogenic effect of many occupational exposures. Point estimates for occupational risks for lung cancer after controlling for smoking range from 9 to 15% (Alberg, Ford, & Samet, 2007). In the United States, the Occupational Safety and Health Administration establishes limits for workers for many of these exposures. In developing countries, worker oversight and protection efforts are often less. Across the world in 2000, an estimated 10% (88,000 deaths) of all lung cancer deaths were attributable to occupational exposures in men and 5% (14,300) in women (Matteis, Consonni, & Bertazzi, 2008).

Air Pollution: Many occupational exposures contribute to both indoor and outdoor air pollution. As mentioned above, radon is an important component of indoor air pollution. Traffic-derived exposures can affect both indoor and outdoor air pollution. Point sources such as factories, smelters, and power plants can contribute to outdoor air pollution (Alberg, Ford, & Samet, 2007). Doll and Peto estimated that 1 to 2% of U.S. lung cancer deaths were attributable to air pollution (1981). Five percent of lung cancer mortality can be attributed to particulate matter in outdoor air pollution. Burning fossil fuels is the primary source of the particulate matter component of air pollution. Two-thirds of the global burden of outdoor air pollution can be attributed to developing Asia (Cohen, et al., 2005).

Radon and ETS are the most important indoor pollutants in the developed world. In the developing world, the burning of biomass fuels for cooking and indoor heating contributes to global lung cancer mortality, especially of women. Approximately 50% of the world's population and up to 90% of households in developing countries use biomass fuels. Women are primarily responsible for cooking and rearing children in these areas and are exposed inordinately to indoor pollutants. Almost two-thirds of female lung cancer deaths in China, India, and Mexico occurred in non-smokers. Odds ratios for lung cancer in Chinese women exposed to coal smoke at home ranged from 2.0 to 6.0 (Bruce, Perez-Padilla, & Albalak, 2000).

Socioeconomic Status (SES): Lung cancer incidence and mortality are higher in those that are poor and less educated (Alberg, Ford, & Samet, 2007). Social class influences exposure to lung cancer risk factors such as smoking, dietary/physical activity factors, and occupational carcinogen exposures. In Canada, the risk for lung cancer was inversely associated with socioeconomic variables, even after adjustment for smoking (Mao, Hu, Ugnat, Semenciw, & Fincham, 2001). In China, a study of lung cancer mortality in rubber workers found a six times higher risk in low income subjects over that of high income subjects (Li & Yu, 2002). Lower SES is associated with lower rates of treatment, more late stage lung cancer diagnoses, and worse cancer survival rates (Tammemagi, Neslund-Dudas, SImoff, & Kvale, 2005). Studies have associated lower SES with less access to health insurance and more comorbidities. All of these factors increase the risk for poor lung cancer outcomes by affecting the amount and quality of healthcare received. Higher mortality rates can be a reflection of poor accessibility of health resources (McDavid, Tucker, Sloggett, & Coleman, 2003).

Comorbidities: Concurrent infections can mask the clinical signs of lung cancer, complicate treatment options, and decrease survival rates. Common comorbidities such as heart failure or chronic obstructive pulmonary disease can hide lung cancer symptoms like chronic cough, chest pain, shortness of breath, loss of appetite, and fatigue (Tammemagi, Neslund-Dudas, SImoff, & Kvale, 2005). In one study, patients waited as long as eighteen months to seek care after initial symptoms were self-associated with comorbidities or smoking (Corner, Hopkinson, & Roffe, 2006). Cooper and Spiro stated that the choice of chemotherapy regimen depended on the patient's comorbidities (2006). The number of comorbidities manifested an inverse association with survival rate (Tammemagi, Neslund-Dudas, SImoff, & Kvale, 2005).

Rural Residence: Approximately 12 million smokers live in rural communities in the United States. Rural smoking prevalence is higher than both suburban and urban prevalence. Rural smokers tend to exhibit a higher smoking intensity (cigarettes per day) than urban smokers. Rural communities also face a growing concern from chronic diseases. The presence of peer influences which affect social norms and the absence of smoking restrictions also present challenges for rural residents. With 20 to 25% of the U.S. population residing in rural communities, more tobacco control programs are needed to address their higher smoking and lung cancer rates (Hutcheson, Greiner, Ellerbeck, Jeffries, Musselman, & Casey, 2008).

Launoy et al. determined that there was an inequality of cancer diagnosis, treatment, and prognosis between rural and urban populations, especially for women

(1992). Other studies have shown that patients in rural areas have inequality of access to cancer treatment and more advanced disease at diagnosis. Patients seen sooner by specialists are more likely to receive effective treatment (Jack, Gulliford, Ferguson, & Moller, 2006). Corner et al. found that older age and geographical location increased the likelihood of delay by individuals to seek care; thus, they had poorer chances of survival because of more advanced disease at diagnosis (2006). Adjusted survival for patients living in rural areas was 9% less than for urban patients (Campbell N. C., Elliott, Sharp, Ritchie, Cassidy, & Little, 2002). Another study found that increased distance from cancer centers was associated with a higher chance of disseminated disease at diagnosis. Therefore, rural patients had less chance of more treatable local stage disease at diagnosis and thus had poorer survival from cancer (Campbell N. , Elliott, Sharp, Ritchie, Cassidy, & Little, 2001). A study of Georgia residents determined that a combination of factors accounted for the urban-rural health disparity. Rural residents had less access to health care services, fewer cancer prevention activities, lower income, and lower educational levels than did urban populations (Liff, Chow, & Greenberg, 1991). Rural-dwelling adults were less likely to have health insurance coverage and travelled longer distances for health care (Hutcheson, Greiner, Ellerbeck, Jeffries, Musselman, & Casey, 2008).

2.1.3 Geographic Information Systems (GIS) Utilization for Spatial Lung Cancer Epidemiology

Lung cancer is the leading cause of cancer deaths in the World. GIS are useful for mapping lung cancer surveillance data, risk factor exposures, and research study spatial parameters presented in a manner to enhance understanding. GIS also provide tools for analysis of data such as smoothing operations, exposure determinations, buffer functions, kriging procedures, and disease clustering studies (Lo & Yeung, 2007). "Place" is an important component of the initial description of any health condition. Numerous researchers now incorporate GIS mapping and analysis into disease and risk factor studies to add context to "place". Mapping also provides a powerful tool when trying to influence policymakers (Novick, 2008). Lung cancer is an important disease that has benefited from GIS.

A study of lung cancer mortality in the state of Ohio used GIS for more robust epidemiological analysis of spatial data. The authors developed a tool that is PC compatible and thus useful to local public health researchers. Ohio county-level lung cancer mortality rates were manipulated to smooth a scattered distribution and present an unambiguous result (Wall & Devine, 2000).

Another study used GIS to link exposure data to residential addresses for a case-control study. They wished to link individual exposures to defined emission-source air pollution. Sites of exposure assessment and residential addresses were geocoded into a GIS (Nyberg, Gustavsson, Jarup, Bellander, Berglind, & Jakobsson, 2000). Addresses entered into GIS for geocoding create a reference on a map through interpolation from known point data (Bostad, 2008). Individual exposures to NO_2 (traffic-related) and SO_2 (heating-related) were calculated and then associated with lung cancer rates. The authors were able to use GIS to determine individual exposures more accurately for their study (Nyberg, Gustavsson, Jarup, Bellander, Berglind, & Jakobsson, 2000).

Bellander et al. created isoline maps to illustrate NO_2 and SO_2 exposure data (2001). Isoline maps use contour lines to display continuous data by producing lines of uniform value (Bostad, 2008). The authors depicted the air pollutant source changes that occurred in Stockholm from 1960 to 1980. They then looked for associations of NO_2 and SO_2 with lung cancer rates (Bellander, Berglind, Gustavsson, Jonson, Nyberg, & Pershagen, 2001).

GIS was used to characterize local traffic contributions to air pollution which can contribute to lung cancer and other mortality in another study. The authors estimated urbanization from address density and calculated distances from freeways and other major roads using GIS. Black smoke and NO_2 exposures were computed from the distances of 100 meters for freeways and 50 meters for other major urban roads (Hoek, Fischer, Brandt, Golbohm, & Brunekreef, 2001).

With GIS, Vieira et al. explored the risk of lung and other cancers in the Upper Cape Cod region of Massachusetts after a reported high incidence rate (2002). Residential addresses of historical data were geocoded and linked to individual health and environmental information. The authors developed a method for smoothing the data that they called adaptive rate stabilization. Circles were generated to encompass at least ten and up to fifty controls which were used to determine case-control odds ratios for the different cancers. Kriging was used to interpolate continuous surface data for mapping within GIS (Vieira, Webster, Aschengrau, & Ozonoff, 2002). Kriging uses least-squares linear regression algorithms to estimate the value of a continuous attribute at any unsampled location using available attribute data (Lo & Yeung, 2007). Isoline maps were generated to show the effect of smoothing lung cancer data within the range of analysis done. Dot maps were created to show the distribution of lung cancer cases and controls within the study area (Vieira, Webster, Aschengrau, & Ozonoff, 2002).

Another study presented lung cancer data to provide a comparison at the county, zip code, and spatial cluster analysis levels for the state of Illinois. Point-based and area-based cluster analyses were described. This study used the "spatial order method" to conduct its spatial cluster analysis. The authors calculated global *R* statistics from exported GIS data and then this data was fed back to GIS for mapping purposes (Wang, 2004). Global *R* statistics use a spatial version of the chi-square goodness-of-fit statistic to detect spatial clusters (Lo & Yeung, 2007). The study applied spatial analysis to emphasize the importance of grouping rare events such as lung cancer to increase statistical power.

Nerriere et al. analyzed spatial data to determine individual exposure parameters for a health impact study of lung cancer mortality (2005). City roads with greater than 10,000 vehicles per day were buffered to 100 meters. Factories were buffered to 250, 1000, or 2000 meters depending on emission levels (Nerriere, Zmirou-Navier, Desqueyroux, Leclerc, Momas, & Czernichow, 2005). Buffering demarcates regions that are less than or equal to a specified distance from one or more features (Bostad, 2008).

The authors mapped lung cancer risk exposure data within these GIS-generated buffer zones.

A study analyzed and mapped radon exposure assessment data and then investigated the relationship to lung cancer mortality. With GIS, a layer depicting a geologic map of Turkey helped in understanding the different radon emission zones (Celik, Poffijin, Cevik, & Schepens, 2007). Layers are graphical data files of related elements that can be “stacked” using GIS to show associations between data (e.g., geographic and health data) (Lo & Yeung, 2007). The authors created isoline maps showing provincial geologic features in conjunction with graduated circles to show respective radon concentrations. The maps effectively related radon levels to geologic formations. This data is important in assessing lung cancer risks.

McEntee & Ogneva-Himmelberger spatially analyzed diesel particulate matter concentrations, lung cancer incidence, and asthma incidence (2008). The concept of an environmental justice (EJ) neighborhood was introduced along with concomitant hot spot spatial analyses. A state-based system called MassGIS was the source of cartographic boundaries for census blocks, towns, and roads. This database also contributed layers representing EJ communities as defined by the state. Hot spot analysis was conducted using a Gi* statistic. A Gi* statistic is computed by summing the concentration of weighted points of neighbors in the sub-region and dividing by the sum of the values for all features. After obtaining *z*-scores by standardizing, the resulting values identify areas where high and low values exist. The authors generated choropleth maps to show hot spot analyses over EJ neighborhood layers to demonstrate lung cancer risk exposures (McEntee & Ogneva-Himmelberger, 2008). Choropleth maps portray quantitative data by area using color graduations (Bostad, 2008).

GIS has proven to be an important tool for analyzing and representing spatial data related to lung cancer and its risk factors. Multiple studies have used GIS to evaluate and map spatial data to increase epidemiologic strength and user understanding. These factors are important to minimize lung cancer incidence through assessing risks, creating effective interventions, and influencing policymakers (Novick, 2008).

2.2 Epidemiology of Lung Cancer in the United States

Lung cancer went from being a rare disease in the United States in the 19th century to becoming the leading cause of cancer mortality in both men and women. Lung cancer mortality lags about 20 years behind tobacco use trends, predominantly cigarette smoking. Smoking causes 85-90% of lung cancer deaths. From 1979-1992, the annual age-adjusted rates of lung cancer deaths ranged from 30.4 per 100,000 for Utah to 93.9 per 100,000 in Nevada. These rates corresponded to the 1992 smoking prevalence rates with Utah having the lowest rate and Nevada, the highest (Mannino, Ford, Giovino, & Thun, 1998). Male lung cancer mortality increased steadily until peaking in 1990 at 75.2 deaths per 100,000 before beginning to decrease (Wingo, et al., 1999). Female lung cancer mortality increased steadily throughout the entire study period (Mannino, Ford, Giovino, & Thun, 1998). Lung cancer mortality in females had been increasing rapidly since 1950 and surpassed death rates from breast cancer between 1986 and 1990

(Escobedo & Peddicord, 1996). Black males consistently had the highest lung cancer mortality rates from 1979-1992 (Mannino, Ford, Giovino, & Thun, 1998).

From 1990 to 1996, Kentucky male and both sex lung cancer mortality rates exceeded those of Nevada at 103.4 and 67.9 deaths per 100,000, respectively. Nevada's female lung cancer mortality rate continued to lead the nation at 45.8 deaths per 100,000. Utah maintained the lowest mortality rates for both sexes at 31.5 per 100,000 in men and 13.9 per 100,000 in females (Wingo, et al., 1999). In 1997, Kentucky's smoking prevalence rate had exceeded that of Nevada's for adult males at 33.1% but Nevada continued to maintain the highest rate in females at 29.8%. Utah persisted in having the lowest smoking prevalence rates for both sexes (American Lung Association, 2008).

In 2005, age-specific male lung cancer mortality continued to decrease in all age groups less than 80 years of age. Age-specific female lung cancer mortality had not yet leveled off in groups older than 75 years of age. Male lung cancer mortality rates for 2001-2005 ranged from 33.7 in Utah to 111.5 in Kentucky per 100,000. The range for female lung cancer mortality rates went from 16.9 in Utah to 55.9 in Kentucky per 100,000. Once again, the state lung cancer mortality trends mirrored the current (2006) smoking prevalence rates with Utah having the lowest smoking rate. Kentucky's female smoking prevalence rate had exceeded Nevada's by this study period; consequently, Kentucky's smoking prevalence rates in both sexes were the highest in the country. From 1996 to 2005, lung cancer deaths in men decreased in all but seven states. Whereas in women, the mortality rate only decreased in three states (California, New Jersey, and

Texas) and increased in 13 states (Alabama, Arkansas, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Kansas, South Dakota, Indiana, Michigan, and Iowa) (Jemal, et al., 2008).

Lung cancer has been associated with high rates of poverty in the United States. Wingo et al. investigated the incidence of lung cancer in Appalachia from 2001 to 2003 (2008). The Appalachian Regional Commission defines and divides Appalachia into three regions. The Central Region includes parts of Kentucky, Tennessee, Virginia, and West Virginia and represents lower SES statistics than the rest of Appalachia or the United States. In the Central Region, the authors found a 71% higher lung cancer rate in males and a 43% higher rate in females than the U.S. rate. Lower SES can affect smoking prevalence, other lifestyle factors, and access to care. Other lifestyle factors include poor diet and less physical activity. Access to care is affected by costs, lack of health insurance, and lower availability of providers and oncologists (Wingo, et al., 2008).

2.3 Epidemiology of Tobacco Use in the United States

One major theme was consistent when examining the epidemiology of lung cancer: mortality follows trends in the addiction to tobacco use, primarily cigarettes (Alberg, Ford, & Samet, 2007). Therefore, the epidemiology of tobacco use is important in understanding patterns of lung cancer morbidity/mortality and predicting future disease burden. Evaluating interventions, identifying high risk groups, guiding research, and policy-making are additional goals of tobacco use epidemiology (Giovino, et al., 1994).

In the early 1880s, only 1% of U.S. tobacco consumption was in the form of manufactured cigarettes. By 1950, 80% of consumption was composed of cigarettes; and in 2006, the percentage had dropped slightly to 79%. Overall U.S. tobacco consumption has decreased for several decades; however, from 1995 to 2006 cigar consumption increased by73%, snuff consumption by 23%, and smoking tobacco by 15%. During this same period, cigarette consumption decreased by 31% and chewing tobacco consumption by 45% (Giovino, 2007).

Cigarette Consumption: In 1900, the U.S. total annual consumption of cigarettes was 2.5 billion cigarettes. The peak consumption was 640 billion in 1981 and was 480 billion in 1994. Consumption per capita was 54 cigarettes annually in 1900. Per capita cigarette consumption peaked at 4,345 in1963 and was 2,493 in 1994 (Giovino, et al., 1994). In 2006, total U.S. cigarette consumption was 372 billion and per capita consumption was 1,691 (American Lung Association, 2008).

Per capita cigarette consumption increased every year from 1901 to 1952 except for 1920, during the first years of the Great Depression, and at the end of World War II. Rising consumption was attributed to increased advertising, the glamorization of smoking in movies, and the lack of information on tobacco's health effects. In the early 1950s, per capita consumption dropped due to early reports on the dangers of cigarette smoking. Per capita consumption renewed its increasing trend in the mid-1950s after a campaign by the tobacco industry which countered the harmful health claims. Consumption increased until 1964, when the report from the Surgeon General's Advisory Committee on

Smoking and Health was released. Per capita consumption decreased for one year and then increased the next two years until 1967. Per capita consumption decreased from 1967 to 1970, went up for two more years, and then has declined every year since. The decrease in consumption was attributed to an increased public awareness of the health hazards associated with cigarette smoking and the benefits of smoking cessation (Giovino, et al., 1994).

Cigarette Smoking Prevalence: In 1965, the Centers for Disease Control and Prevention (CDC) began to assess tobacco use through the National Health Interview Survey (NHIS). The first survey found that 42% of U.S. adults were current smokers corresponding to 52% of men and 34% of women. Since 1965, smoking prevalence has declined in every sociodemographic group examined. In 1991, current smoking prevalence had fallen to 26% overall with 28% for men and 24% for women (Giovino, et al., 1994). In 2006, total smoking prevalence had fallen by 51% since 1965 to 21%. Male current smoking prevalence had decreased to 24% and female prevalence to18% (American Lung Association, 2008).

Number of Smokers: In 1965, there were 50.1 million cigarette smokers in the United States. The number of smokers peaked in 1983 at 53.5 million and had dropped to 46.3 million by 1991 (Giovino, et al., 1994). In 2006, the number of current smokers was 45.3 million and was increasing from a nadir of 44.5 million in 2004 (American Lung Association, 2008). In 2008, there were 23.7 million U.S. female smokers, the highest number in the world. China was second with 13.5 million female smokers. In contrast, 311.2 million males smoked in China (greater than the total U.S. 2008 population of 303.8 million) and 32.5 million U.S. males smoked (Shafey, Eriksen, Ross, & Mackay, 2009).

Intensity of Smoking: In 1974, the NHIS began to capture the number of cigarettes smoked per day to evaluate the intensity of smoking. The numbers were divided into three categories (<15, 15-24, and >24) with >24 cigarettes daily defined as heavy smokers. In 1974, the percentage of those smoking <15 cigarettes daily was 32% and reached a low point of 29% in 1980. The percentage of cigarette smokers that were in the lowest category had climbed to 37% by 1991 (Giovino, et al., 1994). In 2006, the percentage smoking <15 cigarettes daily had increased by 67% since 1974 to 53% of all smokers (American Lung Association, 2008). In 1974, 24% of smokers were classified as heavy smokers. The percentage increased to a peak of 29% in 1980 and then fell to 22% by 1991 (Giovino, et al., 1994). In 2006, the percentage of heavy smokers had dropped by 52% since 1974 to a nadir of 12% (American Lung Association, 2008).

State-level Prevalence of Current Cigarette Smoking: In 1984, the CDC began capturing current smoking by state data through the Behavioral Risk Factor Surveillance System. Of data from the 15 states in 1984 that were surveyed, Illinois had the highest percentage of current smokers at 33.6% and Utah had the lowest at 16.1%. Utah has consistently maintained the lowest percentage of all the states and in 2007, the percentage of cigarette smokers was 11.7%. By 1992, 48 states and the District of Columbia were being surveyed. That year, Nevada had the highest percentage of adult smokers at

30.7%. In 1993, Kentucky's percentage of smokers at 30.1% was the highest in the United States. Kentucky has remained the state with the highest percentage of current smokers every year since except for 1999 (Nevada, 31.5%) (American Lung Association, 2008).

2.4 Demographics of Tobacco Agriculture in the United States

By the time of the arrival of Christopher Columbus in 1492, tobacco use was ubiquitous in the Americas. The first Europeans to smoke were some of Columbus's crewmembers. Tobacco use subsequently spread worldwide concomitant with European colonization. Manufactured cigarettes were first marketed in England in the 1850s (Musk & Klerk, 2003). The cigarette-making machine was developed in 1881 (Cooley, Kaiser, Abrahm, & Giarelli, 2001). All these factors have influenced the growing of tobacco in the United States.

Total American production of tobacco increased from 300 million pounds in the mid-1860s to over a billion pounds in 1909. Production topped 2 billion pounds in 1946 as cigarette consumption grew (Capehart, 2004). Since 1982, production has remained below 2 billion pounds and less than 1 billion pounds since 2001. In 2008, U.S. tobacco production was 801 thousand pounds (U.S. Department of Agriculture, 2009). This placed the United States fourth in tobacco leaf production behind China, Brazil, and India (Shafey, Eriksen, Ross, & Mackay, 2009).

The first year of available USDA statistics, 1866, listed tobacco production from 15 states. By 1950, 21 states were growing tobacco. In 2009, only 10 states reported tobacco production. The 10 states were North Carolina (180,300 acres), Kentucky (83,500 acres), Tennessee (21,600 acres), Virginia (19,600 acres), South Carolina (18,500 acres), Georgia (15,000 acres), Pennsylvania (8,000 acres), Ohio (3,200 acres), Connecticut (2,500 acres), and Massachusetts (1,000 acres). The first six states accounted for 96% of total U.S. tobacco acreage (U.S. Department of Agriculture, 2009). As a consequence, the Southern and tobacco-growing states generally have lower tobacco taxes than other regions (Jemal, et al., 2008).

Since the 1950s, American tobacco acreage and the number of tobacco farms have declined. The number of tobacco-growing farms in the United States dropped from 512,000 in 1954 to 56,977 in 2002. In North Carolina, the number of tobacco farms fell by 95%, from 150,000 in 1954 to 7,850 in 2002. Policy factors such as allowing the lease and transfer of quotas between farms led to acreage aggregation and contributed to the reduction of farm numbers. Also, new technologies such as bulk barns and mechanical harvesters have reduced labor requirements. Average farm acreage was 2.7 acres in 1959 and had grown to 9.0 acres by 2002. In 2002, farm size ranged from an average of 34.6 acres in South Carolina to 2.5 acres in West Virginia (Capehart, 2004).

2.5 Sociobehavioral Risk Factors of Tobacco Use in the United States

Knowledge about the sociobehavioral patterns of smoking can help in the design of public health programs and the targeting of high risk groups. For example, Escobedo & Peddicord found that low educational attainment was associated with a lack of decreased smoking prevalence over time (1996). Persons with less than a high school education had yet to benefit from antismoking campaigns. Lower SES youths had a greater acceptance of smoking than higher SES youths, regardless of race or ethnicity. These youths often lived in a status-conscious society and may have used smoking as a coping response to environmental stressors (Escobedo & Peddicord, 1996). Thus, the authors concluded that public health campaigns directed toward lower SES youth are needed to help decrease smoking initiation.

Tobacco Advertising: The U.S. tobacco industry has a long history of marketing toward certain groups with advertising campaigns. Initially, advertisement campaigns were directed toward men but by 1928, they were aimed toward women. In 1996, the cigarette industry spent $5.1 billion on advertising especially targeted toward women, racial and ethnic populations, blue-collar workers, and adolescents. Cigarette companies have used themes linked to weight control and health consciousness. The so-called “low tar” brand cigarettes were advertised as healthier options; however, smokers tended to take more and longer puffs from cigarettes, inhale more deeply, and block ventilation holes on the filters to get their required amount of nicotine. With the advent of “light” and “ultra-light” low tar brands, the incidence of adenocarcinoma of the lung increased to become the most common U.S. lung cancer type (Wingo, et al., 1999).

As women’s roles in society changed during World War II, cigarette companies began to aggressively target both sexes in their advertising campaigns. Marketing techniques included both prime time television and radio programs where smoking was portrayed as glamorous for women and masculine for men. In 1965, Congress passed the

Federal Cigarette Labeling and Advertisement Act which required health warnings on cigarette packages. After powerful anticigarette commercials appeared to be threatening cigarette sales, the tobacco companies gave up their privileges for television and radio advertising. Consequently, they stepped up their advertising budgets for billboards and print media and sales began to increase. The Universal Tobacco Settlement was approved by the Senate in 1998. The settlement mandated further regulation of tobacco marketing by limiting the type, scope, and target audience of advertising. Prohibitions included outdoor advertising and the use of human images and cartoons. The Internet was off limits for tobacco advertising if the source was accessible in the United States. No tobacco manufacturer, distributor, or retailer was allowed to pay for their product to be a prop on television, movies, or video games. Tobacco brand names, logos, mottos, insignias, selling images, or color patterns could not be used to sponsor any athletic, musical, artistic, social, cultural, or team event (Cooley, Kaiser, Abrahm, & Giarelli, 2001).

Cigarette companies adapted to the Master Settlement Agreement by targeting resources toward the retail environment, bar promotions, and direct mail marketing. They used pricing strategies such as discount coupons and multipack discounts to market cigarette products (Giovino, 2007). In 2001, the tobacco industry spent $11.2 billion for cigarette promotion. As a result, large numbers of youth are still exposed to tobacco advertising. In 2004, 78% of middle school students reported seeing actors using tobacco on television or in movies. Furthermore, 34% reported seeing tobacco advertisements on the Internet (Meyer, Toborg, Denham, & Mande, 2008). Cigarette companies now spend

87% of their marketing dollars to subsidize the price of cigarettes and encourage more consumption (Shafey, Eriksen, Ross, & Mackay, 2009).

Social Norms of Smoking: Stuber et al. defined social norms as the rules or standards that are understood by members of a group which guide social behavior even without the force of law (2008). Smoking by peers, siblings, and parents can influence smoking uptake. In the United States, tobacco growing and tobacco manufacturing have become culturally established and economically powerful enterprises that can influence attitudes about use. Since ETS was labeled as a health risk for nonsmokers, numerous smoke-free air laws and policies were passed to protect the health of workers or residents. Laws protecting nonsmokers can reduce consumption and affect the social norms of smoking (Giovino, 2007). States and cities that have enacted tough tobacco control policies demonstrated a dramatic increase in the social unacceptability of smoking (Stuber, Galea, & Link, 2008). Governments, private industry, and homeowners are involved in regulating tobacco behavior with restrictions on smoking (Brownson, Eriksen, Davis, & Warner, 1997). However, the appearances of smoking in movies and other marketing strategies by tobacco companies have continued to affect smoking as being social acceptable (Giovino, 2007).

National data show that almost 35% of high school students are current smokers. Smoking rates approach 75% among absentees, school dropouts, and other high-risk youths. Peters and colleagues found numerous norms and beliefs on smoking initiation in the themes resulting from a qualitative study (2005). Some examples included peer pressure, older family modeling, cool image, other peer modeling, and peer challenge (Peters, et al., 2005). Parental, peer, and partner smoking increased the likelihood of smoking and decreased the likelihood of cessation (Tehranifar, Liao, & Ferris, 2009). Another study found that parental smoking contributed to the onset of daily smoking by teenagers. This occurred even with parents practicing good family management, holding norms against teen tobacco use, and not involving children in their own tobacco use (Hill, Hawkins, Catalano, Abbott, & Guo, 2005).

Socioeconomic Status: Cigarette smoking is more concentrated among adults from lower SES circumstances. Low childhood and adult SES are associated with increased risk of current smoking (Tehranifar, Liao, & Ferris, 2009). There is an increasing inequality in smoking evidenced by the growing number of lower SES smokers. Cigarette smokers are now more likely to be less educated and poor. Lower SES corresponds with less health literacy and less responsiveness to health promotion messages. The poor have the least information on the risks of smoking, the fewest resources, and the least access to cessation services. Lower SES is associated with persistent smoking which results in a higher burden of lung cancer and other smoking-related disease (Harwood, Salsberry, Ferketich, & Wewers, 2007). A California study of 8^{th} graders found that smoking was more prevalent among youth from lower SES circumstances. They determined that this association existed across racial and ethnic boundaries. Lower SES youths were exposed to a greater concentration of cigarette retailers and storefront cigarette advertising (Unger, Sun, & Johnson, 2007).

Cultural Perspectives: Culture is defined as a set of ideas and behaviors that are learned and transmitted between generations. The perceptions, actions, and relationships among individuals are deeply influenced by culture. A qualitative study of adolescent tobacco use in Appalachia found that residents learned health beliefs and practices within a cultural context. The cultural significance of tobacco within Appalachia is exemplified by the ubiquity of smoking and tobacco growing. Tobacco is the primary cash crop for large portions of Appalachia and has been for decades. Thus, an economic disincentive to tobacco prevention and control coexists with the family history of "always growing tobacco" to influence the cultural milieu. Tobacco can represent a source of ambiguity for some tobacco farmers. Farmers may try to disconnect the agricultural aspect from tobacco use. Even so, tobacco growing represents an important economic contribution to many Appalachian communities. This contributes to the cultural acceptance of its use and argues against attacking the tobacco industry in these areas. Instead of assisting prevention efforts, attacks are likely to be counterproductive with families tied to tobacco cultivation (Meyer, Toborg, Denham, & Mande, 2008).

CHAPTER III

METHODS AND PROCEDURES

3.1 Background

Lung cancer is the second most common cancer diagnosed and the leading cause of cancer deaths in the United States. Lung cancer mortality rates are decreasing for males after a peak in 1990 (Wingo, et al., 1999). The rates for U.S. Black males have always exceeded that of U.S. White males but the gap is closing because U.S. White male lung cancer mortality is decreasing at a slower rate. With the exception of Florida, all the states in the South have higher than average (U.S.) White male lung cancer mortality rates (National Cancer Institute, 2009). This paper explored the possible regional influences associated with the dependent variable of White male lung cancer mortality. The independent variables evaluated were tobacco acreage, percentage rural residence, percentage smoking, percentage poverty, percentage uninsured, and average estimated radon exposure (see Table 1).

3.2 Study Population

State population characteristics were used in this study to look for regional factors associated with White male lung cancer mortality. State-level data were available via the various sites outlined in the data sources section to answer the research questions. Spatial and statistical analyses of state level data were possible using these data. Understanding regional influences are important for resource allocation and policymaking by national public health initiatives. The states with the largest populations in 2007 were California, Texas, Florida, and New York (see Figure 1). In 1997, the states in the South (except Florida) had moderate populations and numbers of farms and the largest number of farms were in Texas. The numbers of farms in 1997 were shown in Figure 1 because that was the latest data available for total farms from ESRI (ArcGIS) and the map helps to show the relative rurality of each state.

Table 1 Demographic characteristics of sample (*N* = 51)

Variable	Min	Max	Mean (SD)
White Male Lung Cancer Mortality (Rate per 100,000 population)	33.5 (UT)	107.9 (KY)	68.41 (15.58)
Tobacco Acreage (Acres in thousands)	0 (DC) (34 states)	250.7 (NC)	13.49 (44.24)
Rural Residence (% rural population)	0 (DC)	61.8 (VT)	27.75 (15.28)
Smoking Prevalence (% current adult smokers)	15.7 (UT)	30.7 (KY)	23.13 (3.06)
Poverty (% people in poverty)	5.6 (NH)	21.6 (MS)	11.83 (3.06)
Lack of Health Insurance (% not covered)	5.4 (MA)	30.3 (WY)	14.37 (5.00)
Estimated Radon Exposure (pCi/L)	≤2.0 (AR,LA, MS)	≥4.0 (IA,ME, MT,ND,WI,WY)	3.09 (0.56)

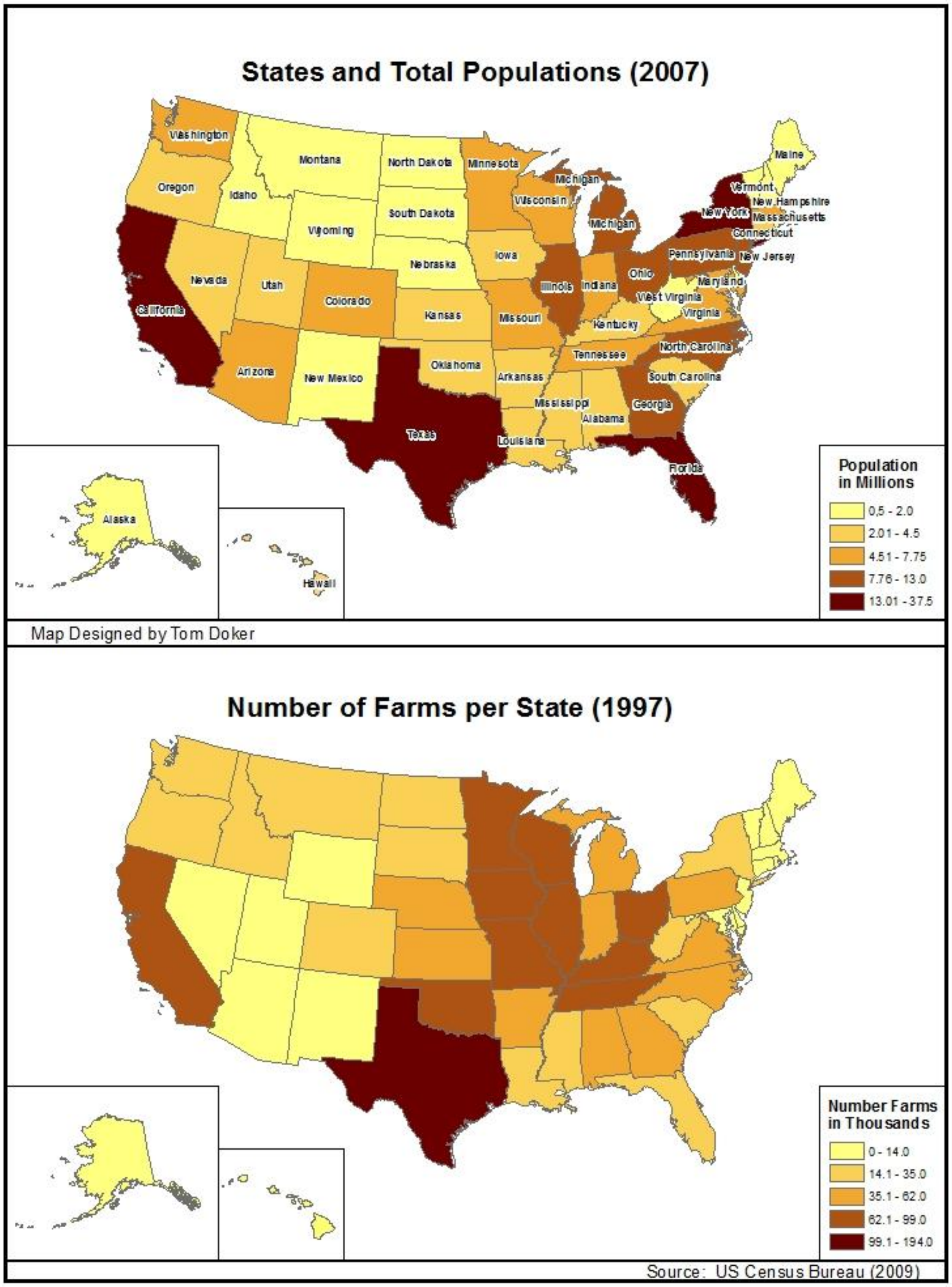

Figure 1 States and selected demographics

3.3 Data Sources

Multiple data sources were required to assess the association of the independent variables for this study. Each source was publicly available and provided by governmental or national organizational databases. Data were chosen from two periods. Historical data were used for the literature review and for analyses of tobacco acreage and smoking prevalence. Lung cancer has a 15 to 30 year lag period associated with the risk factor of smoking. The research question relating to tobacco acreage was concerned with the development of a "tobacco culture" as discussed in the literature review. Thus, tobacco acreage data from 24 years ago and smoking prevalence data from 18 years ago were used to assess an association with White male lung cancer mortality in 2005. Current data were used for rural residence, poverty, and health insurance to look for an association with lung cancer mortality due to lack of access to healthcare. Current data on radon zones were applicable across the entire time period due to the constant decay activity of uranium; consequently, current radon exposures are equivalent to those of 15 to 30 years ago.

3.3.1 Lung Cancer Mortality Data Source

The data for the dependent variable were obtained from the National Cancer Institute's (NCI) State Cancer Profiles, a publicly available database (National Cancer Institute, 2009). State Cancer Profiles are a collaborative effort between the Centers for Disease Control and Prevention and the NCI. The site provides statistics to help analyze cancers at the state and local levels. The purpose of the State Cancer Profiles website is to provide a system to characterize the cancer burden in a standardized manner. The target audiences are health planners and policymakers who need quick and easy access to descriptive cancer statistics. Epidemiologists may also find the site useful for researching cancer statistics. The Profiles website brings together data that are collected from public health surveillance systems by using either NCI published reports or public use files. The data may appear dated but they are the most recent available that have completed the data synthesis and quality assurance processes.

The website provides comparison tables, graphs, maps, and support data for conducting analyses. This study used the death rates provided within the comparison tables. Data was generated using "US by state" for area, "lung and bronchus" for cancer, "White (includes Hispanics)" for race/ethnicity, "male" for sex, and "all ages" for age. Death rates per 100,000 population with 95% confidence intervals, deaths per year, and trends by state were produced using 2005 data. Death data were provided by the National Vital Statistics System public use data file. Death rates were calculated by the National Cancer Institute using SEER*Stat. Death rates were age-adjusted to the 2000 U.S. Census population based on 19 age groups: <1, 1-4, 5-9, … , 80-84, 85+.

Data were then entered into an Excel worksheet for all 50 states and the District of Columbia. Data from all sources were collated onto the same worksheet. The Excel worksheet was then converted to a Statistical Package for the Social Sciences (SPSS®) version 17.0 data file and an ArcGIS® version 9.3 data file for analysis. The worksheet was joined to spatial data within ArcGIS® making data available within the attribute table.

3.3.2 Demographics Data Source

Total populations and the numbers of farms by state were mapped spatially using ArcGIS® 9.3. ArcGIS® provides data layers with shapefiles and associated attribute data. Shapefiles contain the cartographic boundaries for mapping purposes. ESRI supplies these data for use with geographic analyses which give insights into population patterns and trends that can effect planning and decision making. ESRI used 2000 U.S. Census Bureau population data and estimated it to 2007 via a cohort survival model that calculated the components of population change separately (age and sex). The population data for Alaska and Hawaii were retrieved from the U.S. Census Bureau's QuickFacts by state link on the Bureau's home page (U.S. Census Bureau, 2009). The numbers of farms for Alaska and Hawaii were obtained from the U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS), another publicly available database (U.S. Department of Agriculture, 2009).

3.3.3 Tobacco Acreage Data Source

Tobacco acreage was chosen to represent the amount of farmland dedicated to tobacco production in each state. The number of tobacco farms is more difficult to compare between states as farms vary in size from a few acres to thousands of acres. Tobacco acreage was used to contrast tobacco production between the states for qualitative analysis. For quantitative analysis, states were dichotomized as those that did report and those that did not report any tobacco production.

The data for tobacco acreage were also acquired from the USDA's NASS website (U.S. Department of Agriculture, 2009). The NASS conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture including:

crop production, commodity prices, farm labor wages, farm finances, chemical use, and demographic characteristics of U.S. producers. The purpose of the surveys is to provide detailed estimates of crop acreage, crop yields, crop production, and quantities of crops stored on farms. The crop surveys are conducted in all states quarterly.

Farm estimates from the crop surveys are selected from an area and list frame to produce multiple frame estimates. Farm operators from the list frame are selected by size depending on the proportion of commodities of interest. The area frame is added to account for land not covered by the list frame. The sample targets producers of crops with storage capacity on their farms. Operators provide data on the total acres they operate, acreage in each commodity, and amount of production. Each state collects data from a unique set of commodities depending on acreage level and growing season. Farmers' planting intentions are collected in March, acres planted in June, acres harvested in September, and total production in December. Information for specialty crops, such as tobacco, is collected annually in selected-crop producing states. Survey sample size targets are set for each commodity with a minimum overall sample size. Sample sizes range from 65,000 farms in September to 81,000 in June. Data are collected for two weeks beginning the last day of the month prior to the survey reference date. Modes of data collection include mail, telephone, computer-assisted, and personal interviewing. Over 75% of the data are collected by direct and computer-assisted telephone interviewing.

The NASS website offers national and state data via "Quick Stats". By selecting "US & State – crops", the proper "Quick Stats" page was accessed. For this study, data were generated by selecting "planted, harvested, yield, production, price (MYA), value of production" for data type, "tobacco all (all classes)" for data items, from "1866" to "2000" at "1" year intervals for years, and "all States, United States" for location. Tobacco production in thousand pounds and tobacco acreage by year and state were used. Tobacco acreage from 1985 allowed for a 20-year lag time for lung cancer mortality. Lung cancer mortality in 2005 is related more to a possible "tobacco culture" in the past than to current tobacco acreage. Data were added to the Excel worksheet.

3.3.4 Rural Residence Data Source

To help control for the effect of rural residence, percentage rural population data were calculated from rural and total population data available from the U.S. Census Bureau's American FactFinder, a publicly available dataset (U.S. Census Bureau, 2009). For the 2000 census, the Census Bureau's classification of rural consisted of all territory and population located outside of urbanized areas (UA) and urban clusters (UC). UAs and UCs consisted of core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile.

From the American FactFinder website, the author navigated to "data sets" and selected "Census 2000 Summary File 1 (SF 1) 100-Percent Data" and the link for "Detailed Tables". After selecting "state" for geographic type and "all states" for geographic areas and navigating to the "select tables" page, the author selected "P2 Urban and Rural (Total Population)" to get the required data. The detailed table provided the total and rural populations for all 50 states and the District of Columbia. The rural populations were divided by the total populations to obtain the percentage of rural population per state for the year 2000. This data were also added to the Excel worksheet created for further analysis. The most current data available were used since rural residence can affect access to health care for those suffering from lung cancer.

3.3.5 Smoking Prevalence Data Source

The data for smoking prevalence were obtained from the American Lung Association's report on Trends in Tobacco Use (American Lung Association, 2008). The American Lung Association's Epidemiology and Statistics Unit Research and Program Services Branch produces this report yearly on tobacco-related mortality, consumption, prevalence of tobacco use and cessation, advertising and promotion, state laws and secondhand smoke, and international smoking prevalence. The following data were reviewed: cigarette consumption data from 1900 to 2007, number of adults who were current smokers data from 1965 to 2006, percent of adults who were current smokers data from 1965 to 2006, percent of adults who smoke by the number of cigarettes smoked daily data from 1974 to 2006, and current cigarette smoking prevalence among adults by state data from 1984 to 2007. For analysis, smoking prevalence data from 1992 were used, allowing for a 13-year lag time for lung cancer mortality in 2005. 1992 was the first year of reported data with more than 90% of the states reporting. Only Arkansas and Wyoming failed to report in 1992; therefore, Arkansas smoking prevalence from 1993 and Wyoming smoking prevalence from 1995 were used (the first years that data were available from these states).

3.3.6 Poverty and Lack of Health Insurance Prevalence Data Source

Socioeconomic statue (SES) and access to healthcare were possible confounders in this study. As covariates which could potentially affect lung cancer mortality, poverty and lack of health insurance were used as proxies for SES and access to healthcare.

Poverty and lack of health insurance data were available from the U.S. Census Bureau's home page. Current poverty data were available for 2007. Choosing "tables" under "poverty highlights" provided poverty 2007 table options. Data for this study were obtained by selecting "percentage of people in poverty by State using 2- and 3-year averages: 2004-2005 and 2006-2007". The percentages were provided by state with 90% confidence intervals. Household income before taxes was divided by poverty thresholds to determine poverty status. Poverty thresholds vary according to the size of the family and the ages of the members. Originally derived in 1963-1964 using USDA food budgets designed for families under economic stress, the thresholds are updated annually for inflation. Data for "health insurance coverage: 2007" were available and "detailed tables" was selected. "Table H106 Health Insurance Coverage Status by State for All People: 2007" provided the data used in this study. The percent of people not covered by health insurance was given along with standard errors. Data from 2007 were used since poverty and lack of health insurance can affect those with lung cancer who are seeking treatment.

3.3.7 Estimated Radon Exposure Data Source

Radon is the second leading cause of lung cancer following smoking (Barros-Dios, Barreiro, Ruano-Ravina, & Figueiras, 2002). To help control for this potential confounder, an estimate of radon exposure was calculated for each state. Since radon levels do not change appreciatively each year due to the long half-life of its parent element, uranium, current maps of radon levels were averaged to represent state-wide exposures.

The data for estimating radon exposure were obtained from the Environmental Protection Agency's (EPA) Maps of Radon Zones website. The purpose of the map is to assist National, State, and local organizations to target their resources and to implement radon-resistant building codes. Sections 307 and 309 of the Indoor Radon Abatement Act of 1988 directed the EPA to list and identify areas of the United States with the potential for elevated radon levels. The EPA assigned each of the 3,141 counties to one of three zones based on radon potential. Zone 3 counties have a predicted average indoor radon screening level of less the 2 picocuries per liter (pCi/L) and thus represent the *lowest* potential for radon health effects. Zone 2 represented a *moderate* potential for health effects and these counties have a predicted radon level from 2 to 4 pCi/L. Zone 1 counties have a predicted average indoor radon screening level greater than 4 pCi/L and represent the *highest* potential for radon health effects (U.S. Environmental Protection Agency, 2009). Using the map, average estimated radon exposures were determined for each state and assigned to one of five values (pCi/L): 2.0 or less, 2.5, 3.0, 3.5, or 4.0 or greater. Estimates were based on the number of counties in each zone. These data were entered onto the Excel worksheet along with the rest of the study variables.

3.4 Spatial Analysis

Maps were produced to allow for qualitative analysis of the mapped patterns. To answer the first two research questions (regional clustering of White male lung cancer mortality and the association with tobacco acreage), a single choropleth map was created using graduated circles for tobacco acreage. To answer the remainder of the questions relating to smoking prevalence, rural residence, poverty, lack of health insurance, and radon exposure, multiple choropleth maps were created and placed alongside mortality maps for comparison.

The projected coordinate system used for mapping was USA Contiguous Albers Equal Area Conical and the geographic coordinate system was from the North American Datum 1983. All choropleth maps were classified employing natural breaks (Jenks) with five classes. However, since only 16 states reported tobacco acreage in 1985, a thematic map with only three classifications of White male lung cancer mortality was also created (see Appendix B). Natural breaks classification looks for obvious gaps in the data by attempting to identify naturally occurring clusters of data based on an ordering variable. The histograms produced within the classify function showed each variable except tobacco acreage was approximately normally distributed with noticeable gaps in the data. Tobacco acreage data were skewed to the right with the peak at zero (most states reported no tobacco acreage in 1985). Graduated symbols were used for state tobacco acreage.

3.5 Statistical Analysis

Descriptive statistics were produced to determine the mean and standard deviation of each variable using SPSS® 17.0. The first research question was best answered by using spatial analysis. All the data represented quantitative variables. Tobacco acreage had a skewed distribution with the District of Columbia and 34 states not reporting any tobacco production. To better reflect this distribution, tobacco acreage was dichotomized into tobacco acreage reported (variable = 1) and no tobacco acreage reported (variable = 0) within a state. Then, the research questions on the relationship of White male lung cancer mortality to tobacco acreage and the covariates of rural residence, smoking prevalence, poverty, lack of health insurance, and radon exposure were explored using correlation analysis. A Pearson's correlation coefficient was calculated for each possible combination of variables. Next, a multiple linear regression analysis was performed to determine the effect of each independent variable on the response variable controlling for the remaining independent variables. The results of the statistical and spatial analyses were compared.

3.6 Human Subjects Consideration

The Georgia State University Institutional Review Board approved this study as exempt. The study used only publicly available data sources with no discernible connections to individual-level data. All data were assessed at the level of state population.

CHAPTER IV

RESULTS

4.1 Descriptive Statistics

All 50 states and the District of Columbia had data for descriptive statistics (see Table 1). In 2005, White male lung cancer mortality ranged from 33.5 deaths per 100,000 population for Utah to 107.9 per 100,000 for Kentucky. In 1985, the District of Columbia and 34 states reported zero tobacco acreage and North Carolina reported the most at 250,700 acres (see Figure 2). Smoking prevalence and poverty had the least variance in percentages between states. Utah had the least percentage of current smokers in 1992 (15.7%) and Nevada had the most (30.7%). The percentage of people in poverty averaged over 2006-2007 was lowest in New Hampshire (5.6%) and highest in Mississippi (21.6%). In 2000, rural residence had the highest variance between states with the District of Columbia reporting none and Vermont reporting 61.8%. Maine had the lowest percentage of uninsured (5.4%) in 2007 compared to Wyoming with the highest (30.3%). The three states at the mouth of the Mississippi River (Arkansas, Louisiana, and Mississippi) had the lowest estimated average radon exposure. Six states located in the Northern United States had the highest estimated exposures (Iowa, Maine, Montana, North Dakota, Wisconsin, and Wyoming).

4.2 Spatial Analysis

Spatial analyses were conducted for each of the research questions. The first two questions relating to regional influences of White male lung cancer mortality and tobacco acreage were combined into one map. Each of the following research questions had separate maps placed alongside mortality maps allowing for visual spatial interpretation.

4.2.1 White Male Lung Cancer Mortality and Tobacco Acreage

Spatially, White male lung cancer mortality is concentrated in the Southern states, with Florida and Virginia showing lower rates. Many states along the periphery of the South also reflected high mortality rates. Maine was a high outlier in the Northeast. There was a cluster in the four-corners region for the lowest White male lung cancer mortality rates. An association seemed evident spatially as most of the tobacco-growing states showed higher mortality than the other states. However, the amount of acreage did not appear to provide a dose-response relationship. Three states within the highest classification of mortality did not demonstrate any tobacco acreage (Alabama, Arkansas, and Louisiana).

4.2.2 White Male Lung Cancer Mortality and Rural Residence

Analyzing the map for rural residence showed that the rural populations were concentrated in the South (except Florida), extreme Northeast, and upper Midwest (see Figure 3). There were two clusters of the lowest classification of rural residence in the Southwest and Northeast. Examining the two maps concurrently illustrated a correlation in the South and in Maine. However, the upper West cluster of rural states did not associate with concomitant higher White male lung cancer mortality rates.

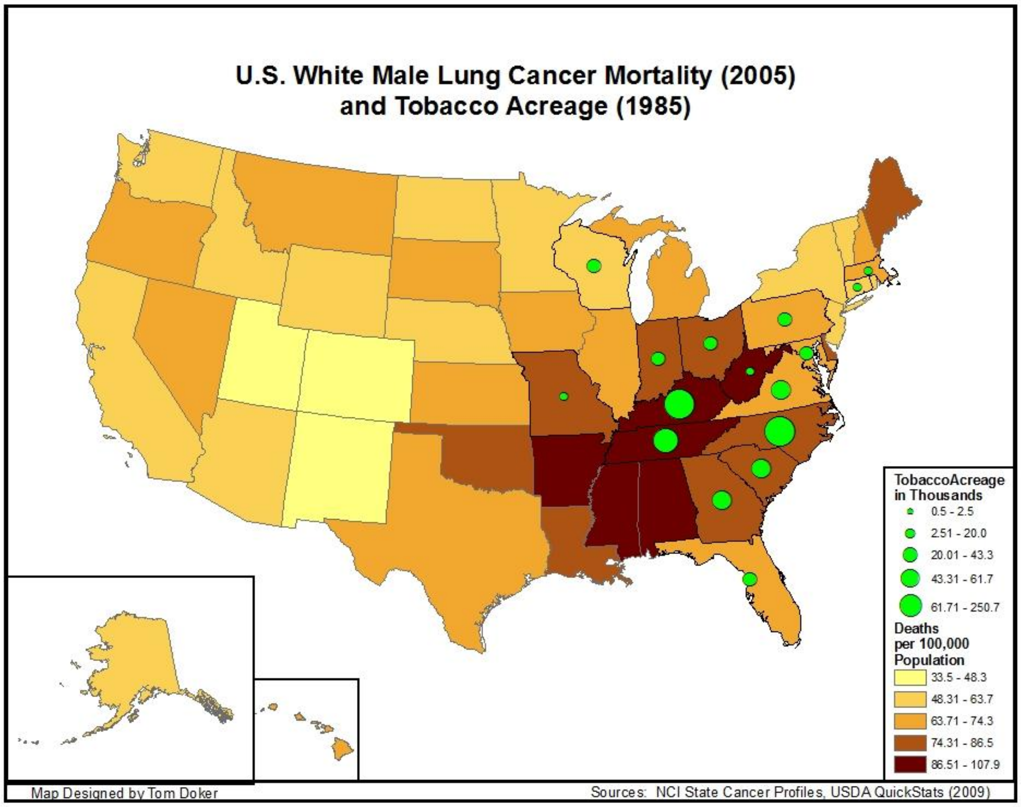

Figure 2 Comparison of White male lung cancer mortality and tobacco acreage

4.2.3 White Male Lung Cancer Mortality and Smoking Prevalence

In 1992, current adult smoking prevalence was highest along a west to east line from Oklahoma to North Carolina and several adjacent states (see Figure 4). Two high outliers were Alaska and Nevada. Four states bordering Nevada, along with Montana, formed a spatial cluster of low smoking prevalence. Analyzing the maps together showed that many of the high smoking prevalence states had associated high White male lung cancer mortality rates. Alaska and Nevada had lower mortality rates that did not correspond with their high smoking prevalence. Alabama and Georgia had higher lung cancer mortality rates that did not match up with their low adult smoking prevalence.

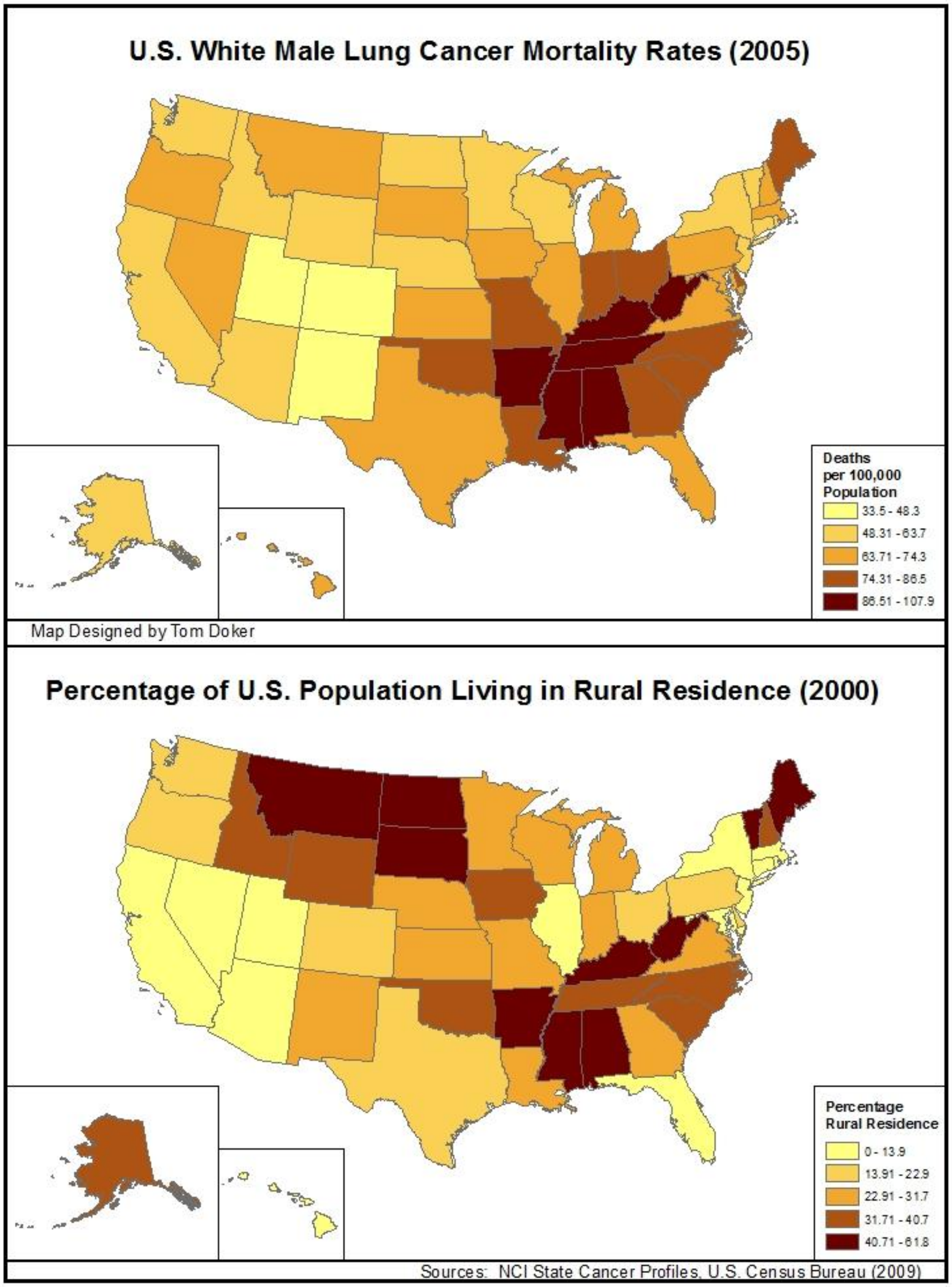

Figure 3 Comparison of White male lung cancer mortality and rural residence

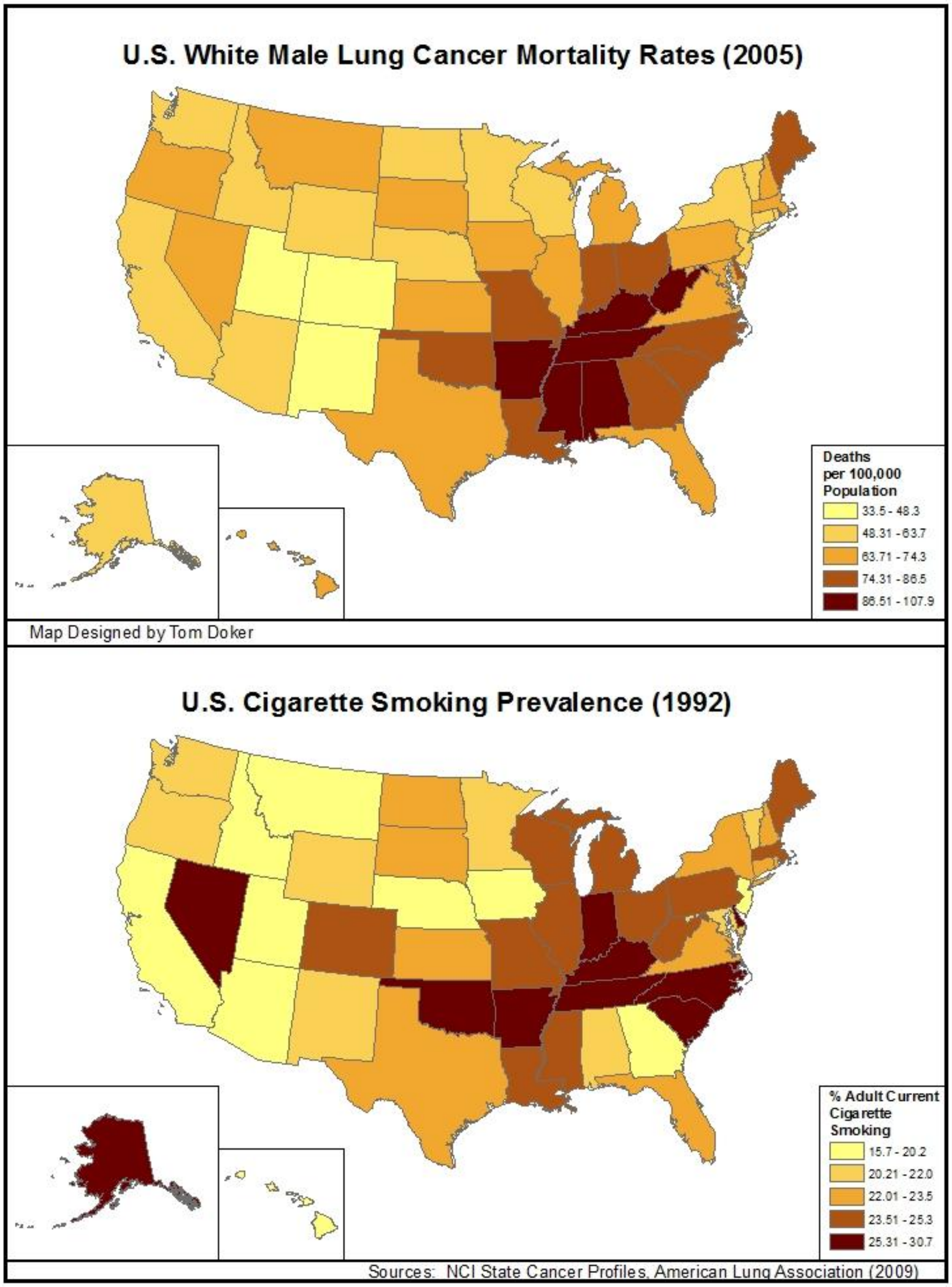

Figure 4 Comparison of White male lung cancer mortality and smoking

4.2.4 White Male Lung Cancer Mortality and Poverty

Generally speaking, poverty prevalence was concentrated in the Southeast and Southwest (see Figure5). Mississippi reflected an extraordinary high level of poverty when compared to the other states as the lone representative of the highest classification of poverty. New York was a high outlier in the Northeast for poverty. Clusters of low poverty were present in the Midwest, central West, and the Northeast. The states with the highest White lung cancer mortality rates and the highest poverty levels demonstrated some association spatially except for Indiana and Maine (these two states showed low poverty). However, the higher poverty prevalence states of Arizona, New Mexico, New York, and Texas did not reflect high lung cancer mortality rates. New Mexico especially did not show an association between its highest poverty prevalence and lowest lung cancer mortality categories.

4.2.5 White Male Lung Cancer Mortality and Health Insurance

Lack of health insurance coverage was also concentrated in the Southeast and Southwest, as well as in states such as Montana, North Dakota, and Oregon (see Figure 6). Alaska and New Jersey were high outliers. Clusters of low levels of uninsured were evident in the Midwest and Northeast. Little overall association was noted between lack of health insurance and White lung cancer mortality rates. All of the states with the highest number of uninsured did not have corresponding high mortality rates. Of the states with the highest lung cancer mortality, only Arkansas and Mississippi had elevated numbers of uninsured.

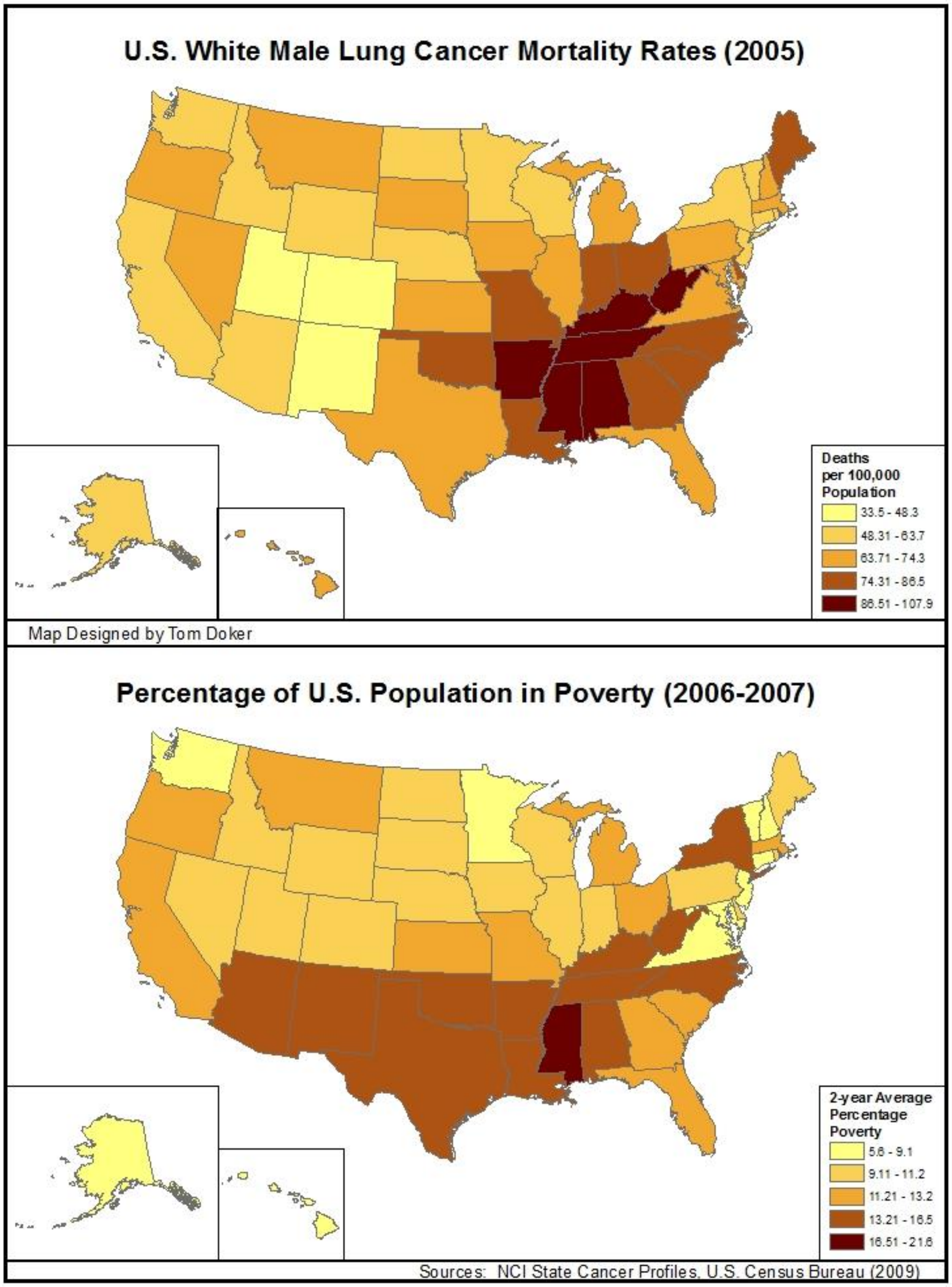

Figure 5 Comparison of White male lung cancer mortality and poverty

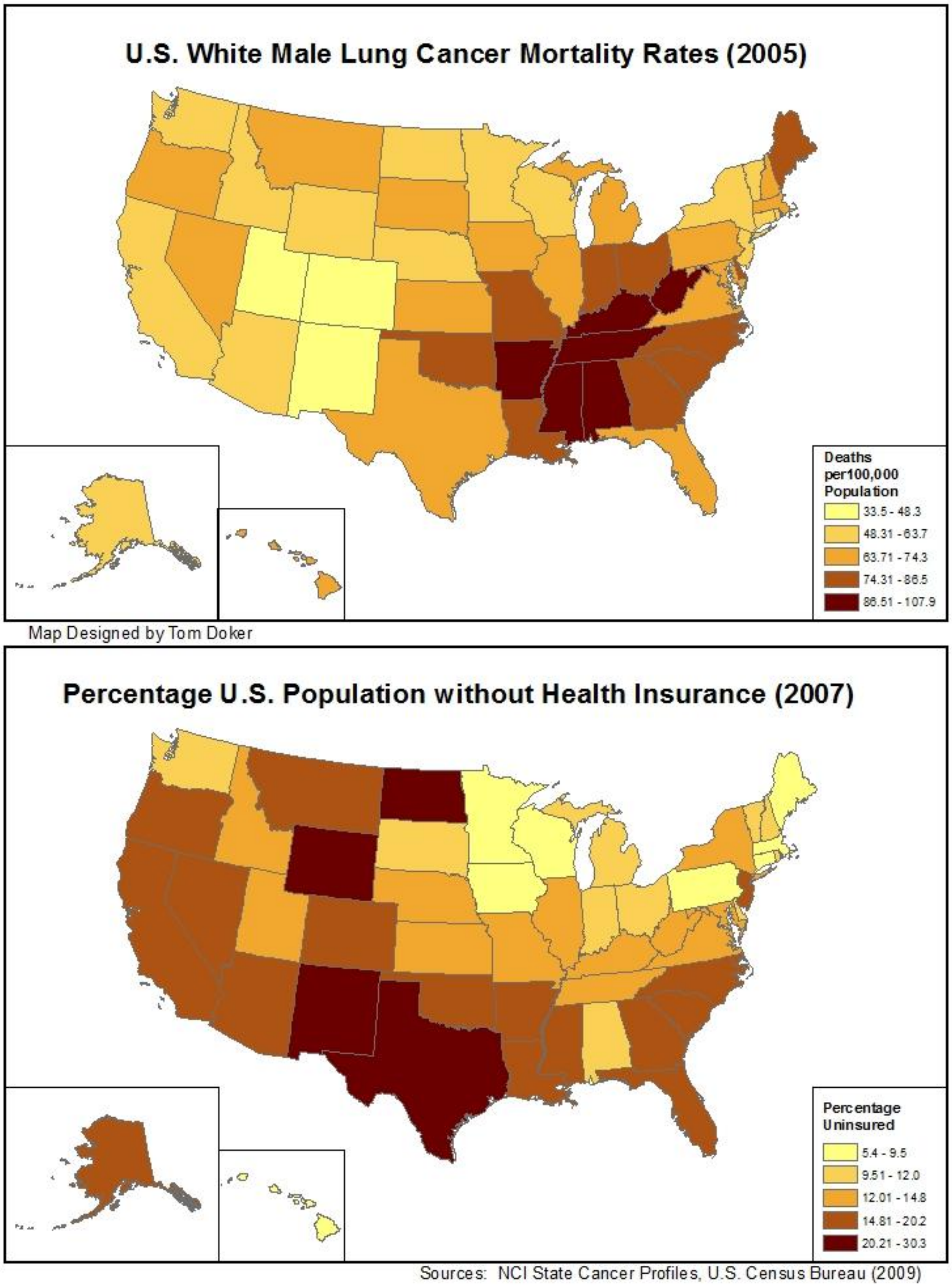

Figure 6 Comparison of White male lung cancer mortality and percent uninsured

4.2.6 White Male Lung Cancer Mortality and Radon Exposure

A cluster of high estimated average radon exposure was evident in the West and Midwest (see Figure 7). A concentration of low radon exposure was present in the states at the mouth of the Mississippi River. The southern half of the United States generally reflected low levels of average radon exposure except for Alabama, Georgia, New Mexico, and Tennessee (which had moderate levels). Little visual relationship between White male lung cancer mortality and average radon exposure was noted except for a moderate association in Indiana, Kentucky, Maine, Ohio, and West Virginia.

4.3 Statistical Analysis

Qualitative spatial analysis is valuable for finding clusters of geospatial data. Statistical analysis is useful to check for associations between risk factors and outcomes along with their statistical significance. Correlations and multiple linear regressions were run with SPSS® 17.0 to see if any associations noted spatially corresponded statistically.

4.3.1 Correlations

Pearson's correlation coefficients were calculated for every possible combination of explanatory and response variable as well as between explanatory variables (see Table 2). White male lung cancer mortality was correlated with smoking (r = .475), tobacco acreage (r = .455), and rural residence (r = .389) at the 0.01 two-tailed significance level. Poverty was also correlated with radon exposure (r = -.370) at the 0.01 two-tailed significance level. At the 0.05 two-tailed significance level, tobacco acreage and

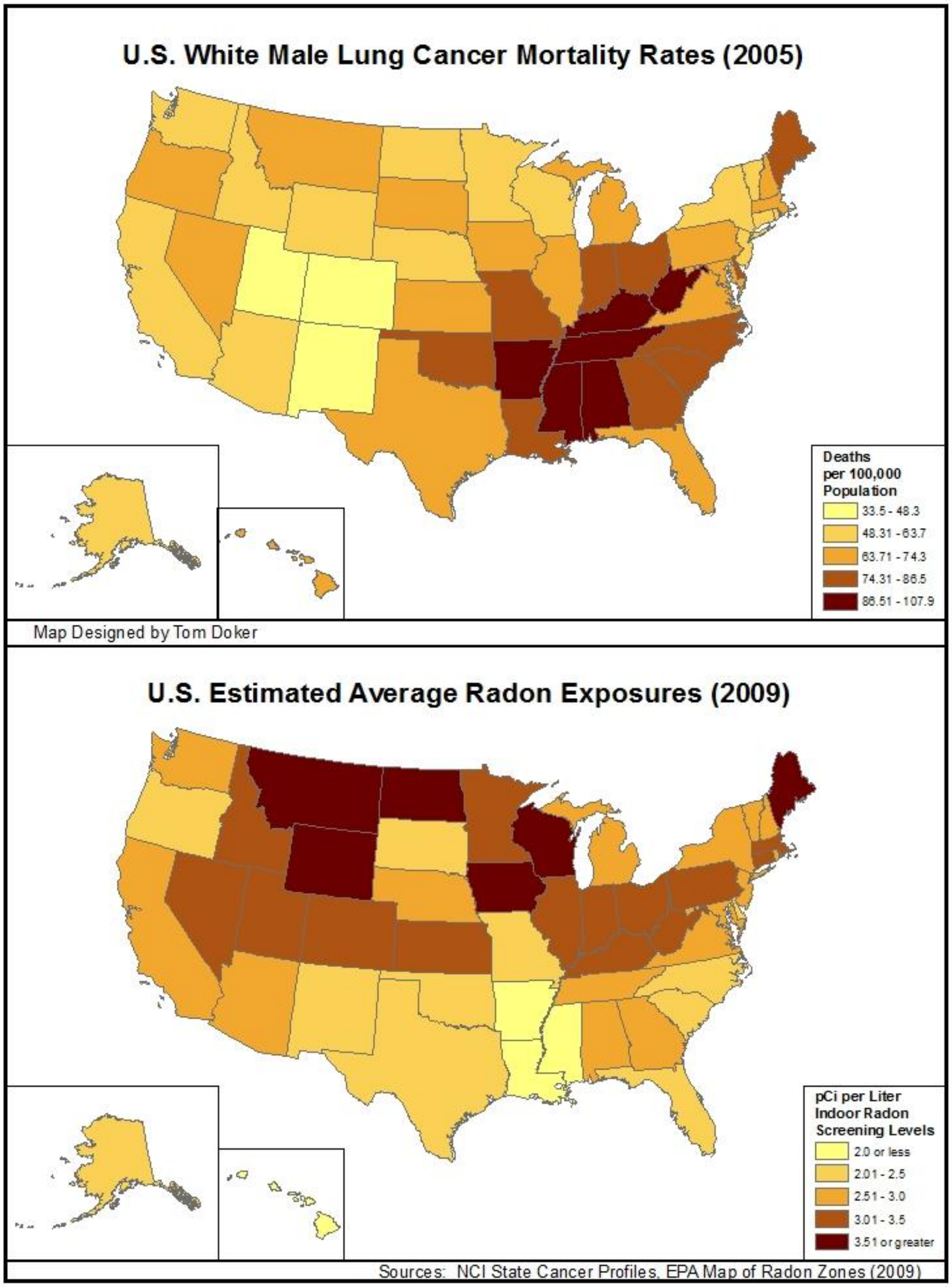

Figure 7 Comparison of White male lung cancer mortality and radon exposure

smoking (r = .283) as well as poverty and lack of health insurance (r = .326) were correlated. All significant correlations were of moderate strength. Of those correlations that were significant, all were positive relationships except for between poverty and radon exposure (r = -.370). All other calculated correlations were not significant.

Table 2 Correlation coefficients for white male lung cancer mortality (LC), tobacco acreage (TA), rural residence (RR), smoking (SK), poverty (PV), lack of health insurance (HI), and radon exposure (RN)

	LC	TA	RR	SK	PV	HI	RN
LC	1	.455**	.389**	.475**	.273	-.104	-.129
TA		1	.021	.283*	.051	-.176	.082
RR			1	.236	.158	.035	.115
SK				1	.138	.041	-.152
PV					1	.326*	-.370**
HI						1	-.172
RN							1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

4.3.2 Multiple Linear Regression

To calculate the effects of the independent variables on the dependent variable when all the factors were considered together, multiple linear regressions were calculated with SPSS®. The multiple R for the model was 0.69 and the R square was 0.48. An analysis of variance procedure used to test the model resulted in a significant F statistic [F (6, 44) = 6.82, p < .001]. Controlling for all the variables, tobacco acreage (p = .005), smoking (p = .030), and rural residence (p = .011) remained significant (see Table 3).

Table 3 Regression coefficients for White male lung cancer mortality as the dependent variable with tobacco acreage, rural residence, smoking, poverty, lack of health insurance, and radon exposure as independent variables

	B	SE	*Beta*	*t*	*p*
Constant	29.87	20.79		1.43	.158
Tobacco Acreage	11.58	3.90	.35	2.97	.005
Rural Residence	0.32	0.12	.31	2.66	.011
Smoking	1.36	0.61	.27	2.24	.030
Poverty	0.89	0.64	.17	1.38	.173
Health Insurance	-0.44	0.37	-.14	-1.20	.237
Radon Exposure	-3.10	3.38	-.11	-0.92	.364

CHAPTER V

DISCUSSION AND CONCLUSION

5.1 Discussion

Lung cancer is one of the most preventable causes of death in the United States with up to 90% attributable to smoking, killing more than 150,000 Americans each year. The United States remains one of the biggest growers of tobacco in the world and much of the burden from lung cancer is born by rural states that often grow tobacco. While both Black and White lung cancer mortality rates are dropping, Black rates are decreasing at a higher pace. Most of the states in the South grow tobacco and have higher White lung cancer mortality rates than the U.S. rate. Often, these rates are parallel with the U.S. rate and show little signs of converging.

This study sought to address the association between White male lung cancer mortality rates and state of residence. Spatial analysis was used to facilitate an evaluation of regional influences. Focusing national public health efforts in regions of high prevalence of lung cancer and its associated risk factors is essential for eventual control. Screening and treatment efforts have failed to make substantial contributions in ameliorating lung cancer mortality. Evaluating the primary risk of smoking for regional factors can lead to effective interventions. States that grow tobacco can be more lax on tobacco control measures such as state tobacco taxes, youth access enforcement, and environmental tobacco smoke regulations. Rural areas within the states can reflect a "tobacco culture" where a combination of family, social, and economic influences can affect tobacco use prevalence. Expanding knowledge on where risk factors are concentrated and the etiology of regional cultural differences can help decrease the incidence of lung cancer.

White male lung cancer mortality and tobacco acreage. In answering this study's first question, results of the spatial analysis show that the highest lung cancer mortality rates occur primarily in the South. To answer the second question, tobacco cultivation was also (and still is) concentrated in the South. There appeared to be a spatial association between lung cancer mortality and the state's tobacco acreage that was borne out by correlation studies. When all factors were taken into consideration with linear regression analysis, tobacco acreage, rural residence, and smoking remained significant. Meyer et al. cited a West Virginia Department of Health and Human Resources study that found that the counties of Appalachia had a higher current smoking prevalence than the U.S. rate (2008). The present study did find a significant correlation between tobacco acreage and smoking.

More in-depth analysis is required to specifically study those counties that grow tobacco in relation to lung cancer mortality and smoking prevalence. Understanding the "tobacco culture" of tobacco-producing counties is important for addressing this regional issue. Tobacco farming is often concentrated within counties and state-level data may not be sufficient for illustrating the more local associations with lung cancer mortality. However, states which grow tobacco may also correlate with more lax tobacco control measures; thus, further research is needed to determine what are the factors within tobacco-growing states that lead to higher White male lung cancer mortality.

White male lung cancer mortality and rural residence. Interestingly, rural residence emerged as having a significant impact on lung cancer mortality. The spatial association appeared weakened by the cluster of rural western states which had low lung cancer mortality. This association between lung cancer mortality and rural residence was also found by Campbell et al. (2002), Launoy et al. (1992), and Liff et al. (1991). These studies showed that patients in rural areas have more advanced disease at diagnosis. Rural residence did not show correlation with any of the other risk factors in this study: tobacco acreage, smoking, poverty, lack of health insurance, or radon exposure. Therefore, much of the effect relating to lung cancer mortality may be from isolation and distance from treatment center factors.

Jack et al. found evidence for inequalities of access to cancer treatment resulting from geographical inaccessibility of services and variations in therapies (2006). Lung cancer treatment centers often reside almost exclusively in urban areas where lung cancer incidence is the highest (National Cancer Institute, 2009). In a Georgia study, Singh et al. found the mean age at diagnosis for lung cancer was 67 and men in the age group 70-79 had the highest incidence of lung cancer (2005). Therefore, older, sicker patients in rural areas may have to travel further to seek care from specialists. Corner et al. found that older age and geographical location increased the likelihood of delay by individuals to seek care; thus, they had poorer chances of survival because of more advanced disease at diagnosis (2006). Consequently, distance from lung cancer specialists is probably one of the factors explaining a White male health disparity for lung cancer mortality. More research is needed to investigate the significant relationship of rural residence and White male lung cancer mortality found in this ecological study.

White male lung cancer mortality and smoking. As mentioned above, 1992 smoking prevalence and 2005 lung cancer mortality showed a significant correlation that was maintained through linear regression analysis. The first major and almost conclusive evidence of the effects of smoking on lung cancer occurred in 1950 with the publication of four retrospective studies by Doll & Hill, Levin et al., Schrek et al., and Wynder & Graham. This study's results drew a parallel with these historical and all intervening studies of the association of cigarette smoking and lung cancer. This study specifically looked at a 13 year lag period of U.S. adult current smoking on White male lung cancer mortality. The spatial analysis contributed by reflecting the regional influences of smoking especially for the South. Smoking proved to be one of the strongest risk factors and remains the primary target for ameliorating lung cancer mortality.

White male lung cancer mortality and poverty, lack of health insurance. The findings of the next two research questions were surprising to the author. Poverty and lack of health insurance were implicated by McDavid et al. (2003) and Tammemagi et al. (2005) as important factors. They noted that lack of access to healthcare resulted in increases in lung cancer mortality. None of the analyses in this study supported this view with the only significant finding being the association of poverty and lack of health insurance. Even though rural populations are linked with lower socioeconomic status (SES), isolation and distance seem more important for explaining the rural residence and lung cancer mortality relationship.

White male lung cancer mortality and radon exposure. To be complete, the leading nonsmoking risk factor for lung cancer, radon exposure, was explored for its association with mortality. Barrios-Dios et al. suggested that residential radon constitutes a risk factor for lung cancer (2002). However, U.S. maps from the EPA show higher potential radon exposures in those states which also exhibit lower lung cancer mortality rates. The spatial and statistical analyses from this study supported this lack of association. This study even reported a slight negative correlation between White male lung cancer mortality and radon exposure. If radon exposure was significant, Northern and Western states with higher potential radon levels should show higher lung cancer mortality rates than the Southern states. With the greater awareness of the risks of radon exposure reflected by increased residential screening and radon amelioration, radon exposure has become less important.

An adjusted R square of 0.48 showed good strength relating to this study's linear regression model with the ANOVA results suggesting a statistically significant amount of variance explained by the included variables. The spatial and statistical analyses showed some parallel and both contributed to the regional findings.

5.2 Study Limitations

A study of this nature has several limitations. First, cross-sectional analysis only permits conclusions to be drawn about associations between White male lung cancer mortality and the included risk factors. Even though historical data were used for tobacco acreage and smoking prevalence, no attempt was made to link individual-level data. Therefore, those growing tobacco and smoking in 1985 and 1992, respectively, were not directly linked to lung cancer deaths in 2005. A prospective study design following a specific cohort of tobacco farmers would enable researchers to understand subsequent smoking and lung cancer patterns.

The study relied on survey results that in turn, were dependent on self-reported tobacco use. The respondents' answers were subject to response bias when identifying themselves or members of their family as current smokers. This study assumed that the results were representative of the state surveyed; however, the states vary in size and demographic makeup. Especially in tobacco-growing counties, state-level data may not truly reflect local conditions.

Cooper and Spiro (2006) and Tammemagi et al. (2005) report that concurrent infections can mask the clinical signs of lung cancer, complicate treatment options, and decrease survival rates. Common comorbidities such as heart failure or chronic obstructive pulmonary disease can hide lung cancer symptoms such as chronic cough, chest pain, shortness of breath, loss of appetite, or fatigue. Corner et al. found that patients waited as long as 18 months to seek care after initial symptoms were self-associated with comorbidities or smoking (2006). Delay of initial lung cancer diagnosis and decreased alternatives for treatment contribute to the lower survival rates of patients with comorbidities; therefore, this study would have been stronger had it controlled for comorbidities.

This study was interested in the investigation of regional influences and thus the results are more important at the national level. The use of state-level data does not capture local (intrastate) patterns which may differ fundamentally from each other. Consequently, these results may not be generalizable to entire states.

For historical data on tobacco acreage and smoking prevalence, this study failed to conduct sensitivity analyses over several years to look for concurrence of results. Lung cancer has a long, variable lag period from smoking initiation to lung cancer mortality and sensitivity analysis would strengthen the study. The study was also limited by the earliest smoking data available. Using data from 1992 did allow for a 13 year lag but a 20 year average lag period for lung cancer mortality may be more applicable.

Other factors associated with SES such as education level and occupation were not assessed. A complete analysis of SES would incorporate several factors which would more completely illustrate the effects of SES with lung cancer mortality. Any study of SES would also benefit from a more local (intrastate) analysis.

In its evaluation of lack of insurance, this study failed to account for the variability between state health insurance policies. Controlling for this inconsistency would better investigate the association of uninsured populations and lung cancer mortality. Consequently, any regional-level analysis of state data may not be applicable. Future research may compare lung cancer mortality between insured and uninsured populations.

5.3 Recommendations

More research is needed to determine if tobacco farming is indeed a predictor of White male lung cancer mortality. Rigorous analyses, such as prospective studies, that take into account individual outcomes, “tobacco culture” factors, and economic alternatives are essential to strengthen outcomes with tobacco agriculture. In addition to smoking and rural residence, there may be other appropriate factors to be measured such as education levels attained or comorbidities. While this study focused on the regional associations of risk factors and White male lung cancer mortality, a more in-depth analysis is required to determine causation.

Continuing to use annual spatial analysis of lung cancer mortality and tobacco use is critical in determining the best methods and regions for intervention. As this study emphasized, smoking remains an important risk factor associated with White male lung cancer mortality. As noted by Danaei et al., it is important to stress that tobacco use is the most preventable cause of mortality in the United States, especially for lung cancer (2009). Pursuing factors that decrease smoking initiation and increase smoking cessation will have the biggest effect on lung cancer mortality.

Not only do results from this study reinforce the need for tobacco control policies, study outcomes show that rural populations may require better access to lung cancer specialists. Without resources, travel is more difficult for aged, sick, and potentially isolated patients to receive adequate healthcare. Higher mortality rates can be a reflection of poor accessibility of health resources. Rural communities need to continue to focus efforts on achieving equable healthcare access for all of their citizens. Linking healthcare resources and a patient's social network is important in overall health outcomes. Even if the primary risk factor of smoking was eliminated, 20 years of diagnosing and treating lung cancer would remain.

Efforts should also be focused on educating policymakers and at-risk populations on how smoking influences lung cancer mortality. Alternatives for tobacco farmers besides subsidizing tobacco agriculture should be sought. The tobacco farm buyout of 2005 was a good start in reducing U.S. tobacco production but farms have since consolidated and are increasing their yields. The international market implies that tobacco leaf will remain available regardless of U.S. production; however, eliminating U.S. tobacco farming would facilitate the dismantling of an existing “tobacco culture” with its associated risk factors for lung cancer.

This study emphasized the importance of using geographic information systems (GIS) to assess risk factors and health outcomes. Public health organizations need to persist with incorporating GIS into their infrastructures to fully analyze the “place” component of descriptive epidemiology in relation to “person” and “time”. The effort to standardize and make GIS data publicly available needs to be united with electronic health information accessibility to help make full use of GIS capabilities.

5.4 Conclusion

Tobacco acreage, smoking, and rural residence significantly influenced regional aspects of White male lung cancer mortality. This study also found an association between tobacco acreage and smoking as well as between poverty and lack of health insurance. It appears that aspects of a “tobacco culture” can have an effect on smoking prevalence especially in the South. Different intervention modalities are needed in tobacco-growing areas to offset the economic realities and prevailing “tobacco culture”. The significance of White male lung cancer mortality and rural residence appears more centered on isolation and geographic distancing factors and not necessarily poverty-related reasons. Consequently, addressing healthcare access can help rural communities to increase survival times for lung cancer patients. However, the primary deterrent to lung cancer mortality is not with treatment, but with prevention of the principal cause, smoking.

This study found that tobacco-growing states have statistically higher lung cancer mortality 20 years later among White males. Also, higher smoking prevalence was significantly associated among residents of tobacco-growing states. More research is necessary to investigate if the social and cultural norms associated with a "tobacco culture" are the primary explanatory factors. Or, is there an association between states that grow tobacco and that state's tobacco control regulatory environment that is the major target for intervention. Regardless, the relationship between tobacco-growing states and smoking prevalence is an important link to explore as public health efforts to decrease White male lung cancer mortality move forward.

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APPENDIX A

BLACK MALE LUNG CANCER MORTALITY AND STATE OF RESIDENCE

Introduction

The purpose of this study was to explore an apparent disparity of White male lung cancer mortality in the Southern states. Six covariates were examined for their association with White male lung cancer mortality. This appendix was developed to investigate the relationship of Black male lung cancer mortality, a proven disparity, with the same explanatory variables used for the main study.

U.S. Black male lung cancer mortality rates are higher than those of White males (National Cancer Institute, 2009). But, Black male lung cancer mortality is decreasing at a faster rate than is White male lung cancer mortality; thus, providing the basis for conducting the primary study. Tobacco acreage, rural residence, and smoking were the significant factors that remained after controlling for the remaining independent variables. Tobacco acreage and smoking were significantly correlated ($r = .283$, $p < .05$). This same relationship would be applicable to an investigation of Black male lung cancer mortality.

This appendix represented an additional study of Black male lung cancer mortality and state of residence using the same covariates developed for the main study.

The quantitative component consisted of calculated Pearson's correlation coefficients followed by a linear regression analysis. A map showing a comparison of White male and Black male lung cancer mortality was created for qualitative analysis.

Methods

The context for this appendix is derived from the main paper. A comprehensive literature review of global and U.S. lung cancer epidemiology along with a review of U.S. tobacco use and agriculture were presented. In addition, the literature review provided background for a study of the sociobehavioral risk factors of tobacco use. From the literature review, a list of explanatory variables was developed. This secondary study is also confined to state-level data. The six covariates used in the main study were used to investigate their relationship with Black lung cancer mortality.

Black males were selected since Black male lung cancer mortality has outpaced White male lung cancer mortality. Data from the National Cancer Institute's (NCI) state cancer profiles was generated similar to the methods in the main study. Pearson's correlation coefficients for Black male lung cancer mortality and the six covariates of tobacco acreage, rural residence, smoking prevalence, poverty, lack of insurance, and radon exposure were generated. A regression analysis was conducted to determine which factors were significant after controlling for the remaining variables. A map was created to allow a qualitative comparison of White and Black lung cancer mortality.

SPSS® 17.0 was used to determine descriptive statistics, calculate correlations, and conduct a linear regression analysis. ArcGIS® 9.3 was used to create thematic maps for comparison of White and Black populations and male lung cancer rates. The same data sources from the main study were employed for this supplementary study. This appendix used the same exempt (Georgia State University Institutional Review Board) publicly available data that was imported for the main study.

Results

The descriptive statistics for Black male lung cancer mortality had a mean of 62.75 and a standard deviation of 45.80. The District of Columbia and 16 states had less than 15 reported Black male lung cancer deaths and thus the NCI did not provide rates for these areas. Arkansas had the highest Black lung cancer mortality at 121.9 deaths per 100,000 population (see Table 4).

Table 4 Demographic characteristics of sample (N = 51)

Variable	Min	Max	Mean (SD)
Black Male Lung Cancer Mortality (Rate per 100,000 population)	<15 cases (DC) (16 states)	121.9 (AR)	62.75 (45.80)
Tobacco Acreage (Acres in thousands)	0 (DC) (34 states)	250.7 (NC)	13.49 (44.24)
Rural Residence (% rural population)	0 (DC)	61.8 (VT)	27.75 (15.28)
Smoking Prevalence (% current adult smokers)	15.7 (UT)	30.7 (KY)	23.13 (3.06)
Poverty (% people in poverty)	5.6 (NH)	21.6 (MS)	11.83 (3.06)
Lack of Health Insurance (% not covered)	5.4 (MA)	30.3 (WY)	14.37 (5.00)
Estimated Radon Exposure (pCi/L)	≤2.0 (AR,LA, MS)	≥4.0 (IA,ME, MT,ND,WI,WY)	3.09 (0.56)

The correlation analysis found significant positive relationships between Black lung cancer mortality and tobacco acreage (*r* = .361), smoking (*r* = .390), and poverty (*r* = .373). All the coefficients were significant at the *p* = .01 level (2-tailed). The correlation coeffiecients between the independent variables were the same as for the main study (see Table 5).

Table 5 Correlation coefficients for Black male lung cancer mortality (LC), tobacco acreage (TA), rural residence (RR), smoking (SK), poverty (PV), lack of health insurance (HI), and radon exposure (RN)

	LC	TA	RR	SK	PV	HI	RN
LC	1	.361**	-.140	.390**	.373**	-.116	-.178
TA		1	.021	.283*	.051	-.176	.082
RR			1	.236	.158	.035	.115
SK				1	.138	.041	-.152
PV					1	.326*	-.370**
HI						1	-.172
RN							1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

A regression analysis of Black lung cancer mortality and all the explanatory variables was performed. The multiple *R* for the model was 0.66 and the *R* square was 0.44. An analysis of variance procedure used to test the model resulted in a significant *F* statistic [F (6, 44) = 5.73, $p < .001$]. Controlling for all the variables, poverty ($p = .002$), smoking ($p = .007$), and rural residence ($p = .020$) remained significant (see Table 6).

Table 6 Regression coefficients for Black male lung cancer mortality as the dependent variable with tobacco acreage, rural residence, smoking, poverty, lack of health insurance, and radon exposure as independent variables

	B	SE	*Beta*	*t*	*p*
Constant	-93.25	63.60		-1.47	.150
Tobacco Acreage	19.98	11.93	.20	1.68	.101
Rural Residence	-0.87	0.36	-.29	-2.41	.020
Smoking	5.27	1.86	.35	2.83	.007
Poverty	6.56	1.96	.44	3.35	.002
Health Insurance	-2.05	1.12	-.22	-1.83	.074
Radon Exposure	1.26	10.34	-.016	0.12	.903

A map was created for a qualitative analysis of Black male lung cancer mortality (see Figure 8). A thematic map of White male lung cancer mortality was placed alongside to allow comparison. A cluster of high Black male lung cancer mortality is evident in the center of the country from Minnesota south to Louisiana. Taking into account that the top three classifications for Black male lung cancer mortality are comparable to the top two White male lung cancer mortality classifications, the South (except Florida) also exhibited high lung cancer mortality. California, Massachusetts, and Nevada represent high outliers. Two clusters of low Black male lung cancer mortality were seen in the Midwest and the Northeast. Low outliers included Alaska, Hawaii, and West Virginia.

Another map of White and Black populations in 2007 was generated to permit comparison of male lung cancer mortality and state population (see figure 9). Comparing the highest classifications (natural breaks), both populations shared California and Texas; however, Blacks also exhibited the highest classification of population in Georgia,

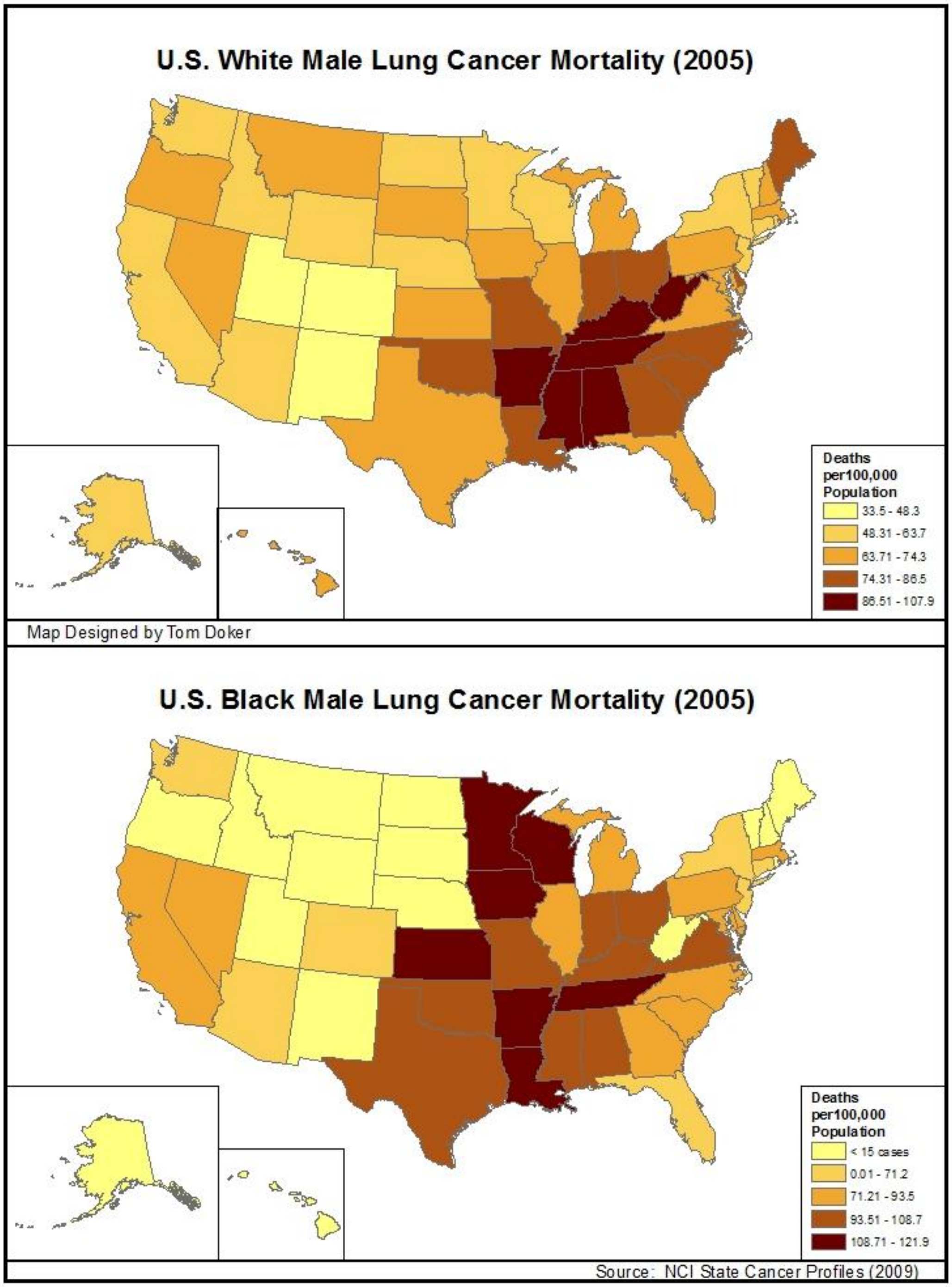

Figure 8 Comparison of White and Black male lung cancer mortality

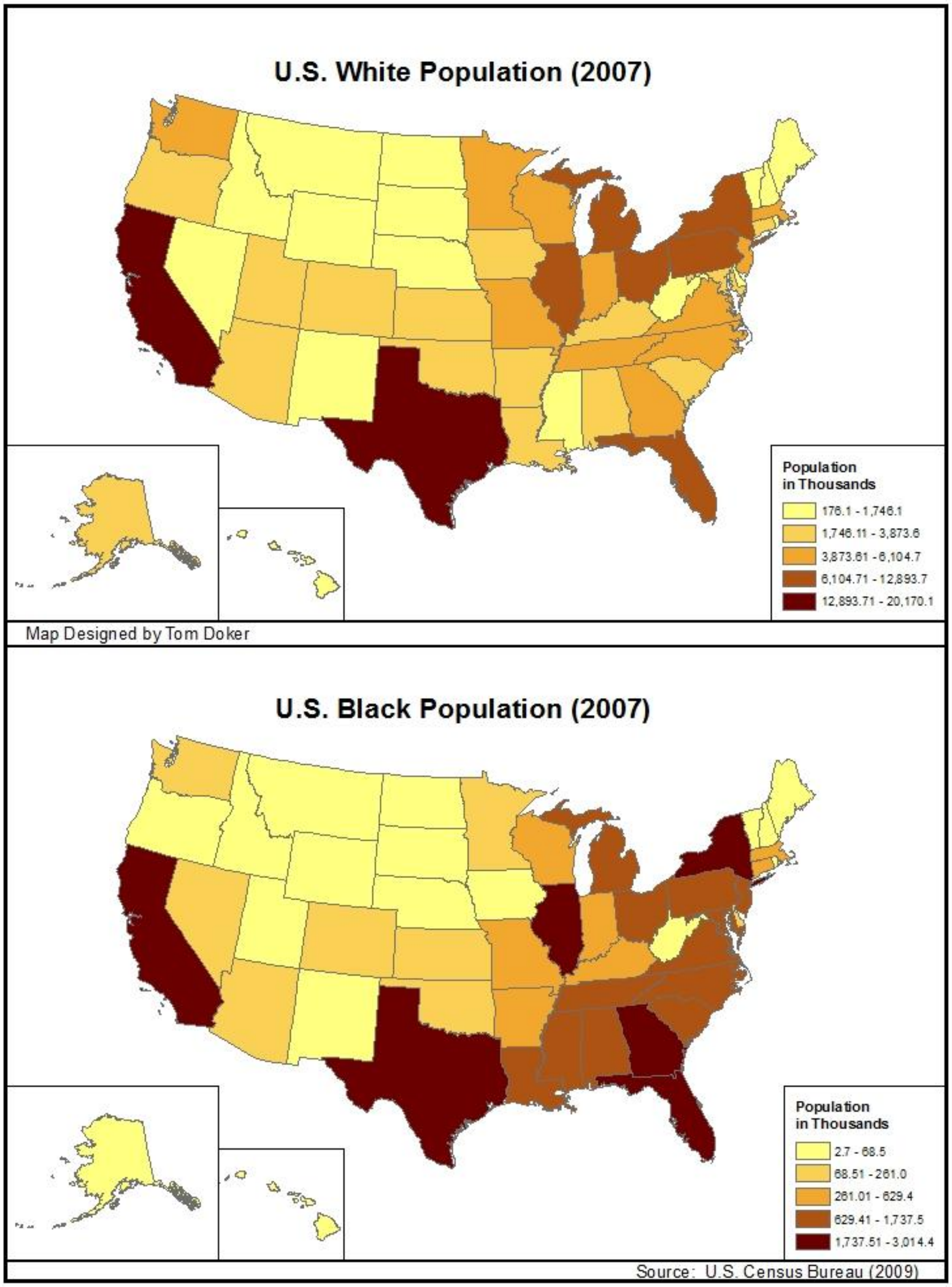

Figure 9 Comparison of study populations

Florida, Illinois, and New York. Both populations showed the lowest levels in 14 states (Alaska, Hawaii, Idaho, Maine, Montana, Nebraska, New Hampshire, New Mexico, North Dakota, Rhode Island, South Dakota, Vermont, West Virginia, and Wyoming). The White population also demonstrated the lowest ranks in Mississippi and Nevada. In addition, the Black population was the lowest categorization in Iowa, Oregon, and Utah.

Discussion and Conclusion

In order go beyond exploring the possible risk factors for White male lung cancer mortality, this addendum wished to investigate Black male lung cancer mortality using the same independent variables developed for the main study. Even though White male lung cancer mortality is high in the South and in Maine, the highest state Black male lung cancer mortality (Arkansas) is 13% higher than the highest state White male lung cancer mortality (Kentucky). The strongest study finding for the main study was that states that grew tobacco 20 years prior had statistically higher White male lung cancer mortality. For the addendum study, the strongest finding was that states that reported the highest poverty percentages had statistically higher Black male lung cancer mortality (tobacco acreage was not significant).

Black male lung cancer mortality and poverty. The most significant factor for Black male lung cancer mortality was poverty when all remaining independent variables were considered. This is an important demarcation from the main study in that poverty was not significant with White male lung cancer mortality. Different public health interventions are required to address the dissimilar findings. In addition to investigating why states that grow tobacco have higher lung cancer mortality (in White males), these results suggest that studies of states that have a higher percentage population in poverty and lung cancer mortality (in Blacks) should be explored.

Black male lung cancer mortality and smoking. Smoking was found to be a significant association with Black male lung cancer mortality for the same reasons as presented in the main study. Danaei et al. found smoking to be the most preventable cause of death in the United States including lung cancer (2009). A study by Albert et al. reported that 90% of lung cancer can be attributed to smoking (2007). Public health interventions are needed to reduce smoking in both White and Black males on the way to decreasing lung cancer mortality in both populations.

Black lung cancer mortality and rural residence. The third of three significant independent variables when all the remaining variables were considered was rural residence. Rural residence was also a significant finding in the primary study; however, the association for Black males was opposite that for White males. States that have increased rural population have significantly lower Black lung cancer mortality. While research is needed investigating the relationship of White male lung cancer mortality in rural areas; for Black males, study efforts may require looking in areas which are not rural.

Black lung cancer mortality and tobacco acreage. While the strongest significant factor for White male lung cancer mortality, tobacco acreage proved not significant for Black males in this secondary study. Whatever causal factors that may exist in tobacco-growing states to explain concomitant higher lung cancer mortality in White males do not seem to be significantly associated with Black male lung cancer mortality. Therefore, the primary focus for research in states that grow tobacco should be on White male lung cancer mortality.

Black lung cancer mortality and health insurance, radon exposure. These two explanatory variables were not significant for either White or Black lung cancer mortality. More research is needed into why Black male mortality is associated with poverty but not lack of health insurance. Other factors must be important in the causal chain from living in a high poverty state and higher Black male lung cancer mortality than simply lack of health insurance. Radon exposure, as the second most common cause of lung cancer, seems not to present a significant risk at the state level.

Black lung cancer mortality and qualitative regional analysis. Five of the six states (Alabama, Arkansas, Kentucky, Mississippi, and Tennessee) that reflected the highest classifications of lung cancer mortality on the thematic map were the same for White and Black lung cancer mortality. West Virginia was one of the states that reported the highest classification of White male lung cancer mortality; however, less than 15 cases of Black lung cancer mortality were reported for the entire state in 2005. Maine also reported less than15 cases of Black male lung cancer mortality; yet, the second highest classification of White male lung cancer was reported. With lower relative Black populations, the true rates for these two states may still be high; however, not enough Black male deaths (>15) were reported for the NCI to present mortality. The four-corners states (Arizona, Colorado, New Mexico, and Utah) represented the lowest mortality for both White and Black male lung cancer. Sixteen states reported less than 15 Black male deaths for 2005. All these states also reported the lowest numbers of Black population.

This additional study shares the same strengths and limitations as the main study. The addendum did add an investigation of a racial group that has manifested a traditional health disparity in the United States. Though Black males exhibited higher lung cancer mortality, White males suffered the most overall number of deaths from lung cancer mortality due to substantially higher population. The difference in findings between White and Black male lung cancer mortality and the six variables studied revealed that different research and interventions will be needed to address the two populations.

While focusing on why tobacco-growing, rural states are associated with higher White male lung cancer mortality, the focus for Black male research is why their lung cancer mortality was related to poorer, less rural states. Both populations showed a significant association with smoking, so interventions that decrease the causal factor of smoking need to be continued to reduce lung cancer mortality in both races.

APPENDIX B

WHITE MALE LUNG CANCER MORTALITY (THREE CLASSIFICATIONS) AND TOBACCO ACREAGE

Five classifications were presented in the main study maps for all the investigated variables; however, only 16 out of 50 states and the District of Columbia reported tobacco acreage. Considering this paucity of tobacco-growing states, a map showing only three White male lung cancer mortality classifications was generated to strengthen the visual correlation (see Figure 10). This map may be a better assessment of the association for policymakers to grasp.

Moreover, the strong clustering of high White male lung cancer mortality in the South is highlighted as well as three clusters of low mortality in the Midwest, Northeast and West. This map is useful when decisions on national lung cancer campaigns are being considered. Results suggest that White males need further targeting in the South.

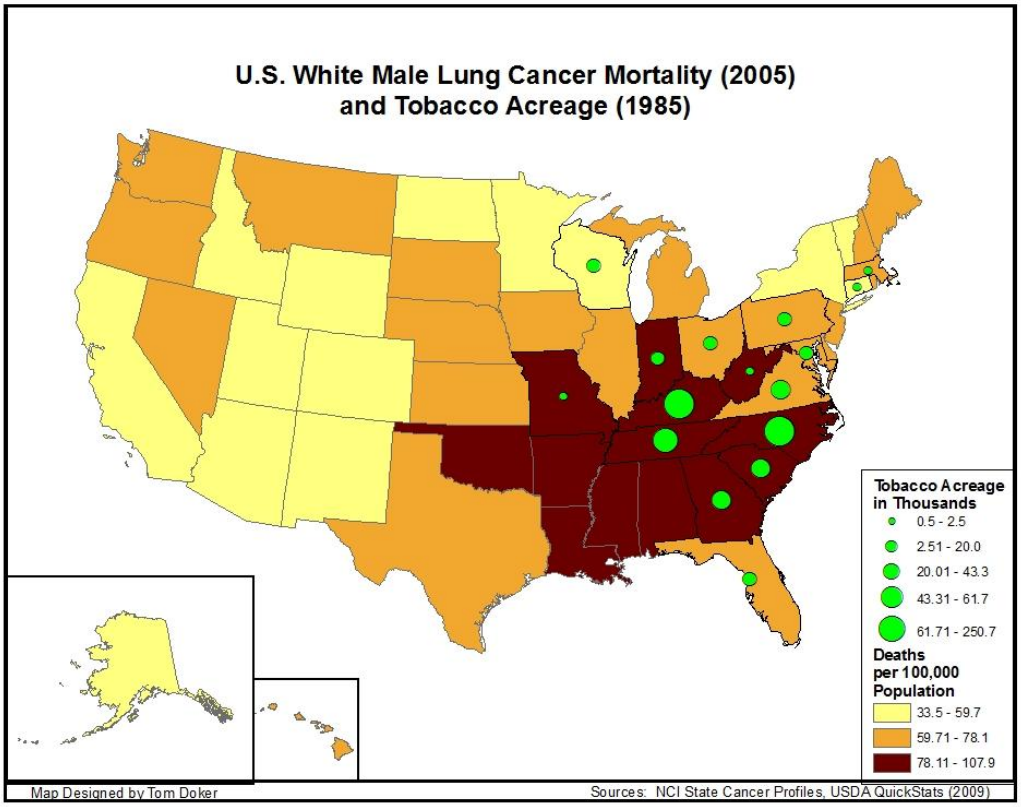

Figure 10 White male lung cancer mortality (three classifications) and tobacco acreage