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Green Gold- a Cannabis Sativa L. Lucis Suitability Analysis for West Virginia

Delbert Christopher Cannoy
Marshall University, cannoy1@marshall.edu

GREEN GOLD- A *CANNABIS SATIVA L*. LUCIS SUITABILITY ANALYSIS FOR WEST VIRGINIA

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Delbert Christopher Cannoy
Approved By
Dr. Kevin Law, Committee Chairperson
Dr. Godwin Djietror
Dr. Joshua Hagen

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APPROVAL OF THESIS

We, the faculty supervising the work of Delbert Christopher Cannoy, affirm that the thesis, *Green Gold- A Cannabis Sativa L. LUCIS Suitability Analysis for West Virginia*, meets the high academic standards for original scholarship and creative work established by the Masters of Science in Geography and the Marshall University Graduate College. This work also conforms to the editorial standards of our discipline and the Graduate College of Marshall University. With our signatures, we approve the manuscript for publication.

Dr. Kevin Law, Department of Geography	Committee Chairperson	12/7/15 Date
Dr. Joshua Hagen, Department Chair Department of Geography	Committee Member	12/07/15 Date
Dr. Godwin Djietror, Department of Geography	Committee Member	12/07/15 Date

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Appalachia needs a way to sustainably develop. *Cannabis Sativa L*. may be a possible source of sustainable development for West Virginia. The goal of this study is the identification of possible sites for industrial hemp fiber cultivation areas, both the total agricultural potential and with current land use land cover classification limits, and which of these sites have the potential for acid mine drainage phytoremediation.

Using LUCIS classification and binary analysis, three major separate outputs were created answering the three study questions. The agricultural layer revealed that West Virginia can utilize hemp farming for 23.48% of the state. The second output, urban layer, reduced the amount of hemp suitable sites to 2.89% of the state. Hemp suitable sites were carved by adding stakeholder preferences reducing the suitable sites to 2.71%. The last layer, contamination, revealed that 1.28% percent of the state is capable of performing phytoremediation under the current classification.

CHAPTER ONE

INTRODUCTION

The Appalachian region needs more environmentally sustainable industries because coal extraction opportunities are disappearing as a viable means to produce energy due to climate change concerns over coal powered energy plants contributing to rising global CO_2 emissions. The sustainable development path will both preserve the environment, while contributing towards economic growth for the Appalachian region. Nowhere is this truer than in the state of West Virginia, an area devastated by the decrease of coal extraction economic opportunities as a major industry and located within the Appalachian region. So began a quest to discover a sustainable and ecologically responsible way to plan and develop the landscape, while still creating potential economic development opportunities for West Virginia. *Cannabis Sativa L.* or Industrial Hemp cultivation was considered to be such an opportunity for sustainable development.

The agricultural suitability of any crop is very dependent upon the right location for success. West Virginia spans 5 degrees of longitude from 77° 40'W to 82° 40'W and spans 3.5 degrees of latitude from 37° 10'N to 40° 40'N as evidenced in Figure 1, also indicating the global context for the state in relation to other hemp producing countries. West Virginia is a landlocked region surrounded by other states: Ohio and Kentucky from the west, Virginia from the south and part of the eastern border, Maryland along the eastern portion and part of the northern border and Pennsylvania from the north. West Virginia is the only American state fully located within the Appalachian region according to the Appalachian Regional Commission in Figure 1. West Virginia is geographically located in the mid latitude climate zone with the prevailing westerly winds blowing eastward toward the Atlantic Ocean. West Virginia generally experiences mid-latitude cyclones which move consistently across the United States in an eastward direction into the Ohio River Valley and eventually into the Appalachian Mountains.

The western border of the state is framed by the Ohio River from which the many West Virginia streams drain from their watersheds into the Mississippi River.

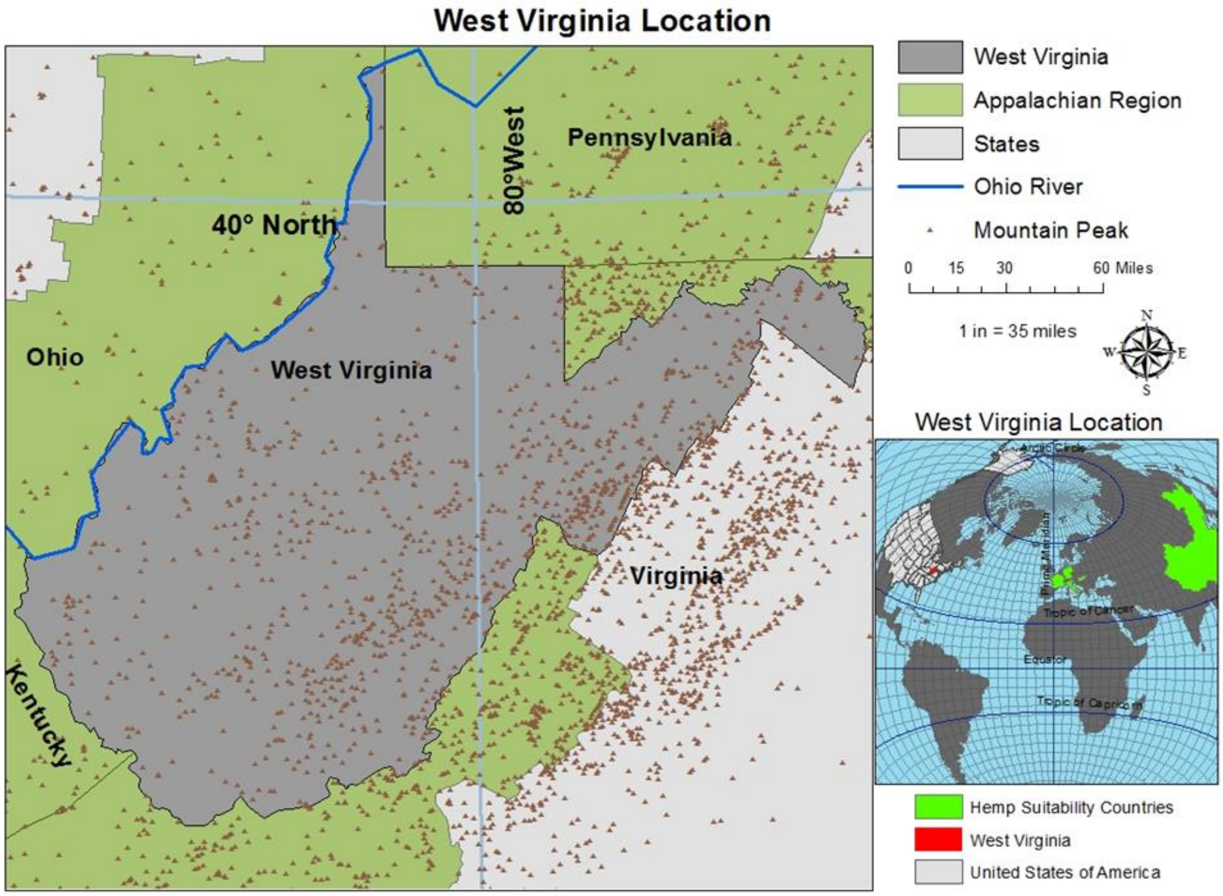

Figure 1 – The Location of West Virginia in the United States and Globally.

Cannabis Sativa L. or industrial hemp appeases both West Virginia's economic needs by positively stimulating the West Virginia economy and also environmentally by the phytoremediation of the acid mine drainage soil. Industrial hemp cultivation has one major problem which is the stigma of being often associated with Marijuana, the schedule one federally controlled and prohibited drug. This association is often made when the discussion of industrial hemp takes place even though they are different plants. Johnson (2015) describes the differences between the two similar plants by stating

> "Hemp is genetically different and is distinguished by its use and chemical makeup, as well as by differing cultivation practices in its production. Hemp, also called "industrial

> hemp," refers to cannabis varieties that are primarily grown as an agricultural crop (such as seeds and fiber, and by-products such as oil, seed cake, hurds) and is characterized by plants that are low in THC (delta-9 tetrahydrocannabinol, marijuana's primary psychoactive chemical). THC levels for hemp are generally less than 1%."

Therefore the legal woes that accompany Marijuana should not be associated with cultivating industrial hemp, *Cannabis Sativa L*., in West Virginia.

West Virginia legislators, in an effort to help stimulate the economy, legalized the cultivation of hemp in 2002. In addition to legalizing hemp cultivation, "this legislation also established licensing procedures to allow local farmers to plant, grow, harvest, possess, process, and sell hemp commercially" (Haas, 2013). However, the process for supervising hemp cultivation has been stagnant because of a lack of state funding and not because the legality of hemp cultivation was questionable by the state of West Virginia, but because of Federal regulations. The general attitude is "the Department expects to take no action in the absence of guidance or a more permissive attitude by federal authorities" (Haas, 2013). Therefore, the question is not if industrial hemp cultivation is legal, but rather *where* in West Virginia can industrial hemp fiber cultivation sites be found. By answering this agricultural focused question another inquiry arises, how does current land use classification affect the availability of industrial hemp cultivation sites within the state? Also, do these sites have the possibility of contamination due to acid mine drainage, by identifying potentially hazardous hemp cultivation sites? These questions are the central focuses of this study as developed through a planning based spatially represented model distilled into three major cartographic outputs identifying areas of cultivation potential, current landuse conflict, and areas of potential phytoremediation efforts-all three outputs could be utilized to attract new industries to the area.

CHAPTER TWO

LITERATURE REVIEW

Planners are the catalyst for development and change in any area. Environmental sustainability as a principle of planning has an increasing importance because of these rising global trends: human demographic rates, urbanization rates, and the decreasing physical environment's carrying capacity. Historically, planning has relied upon differing academic disciplines for a basic theoretical framework. The realization that climate change is real and currently occurring has spurred several new planning ideas exploring the boundaries of what it really means to plan in an environmentally sustainable way.

A contemporary explosion of hemp-based research has been published and as a result several different hemp cultivation suitability analyses have been performed globally and have been consulted when framing this suitability study. Geographically the hemp cultivation studies consulted are focused wholly within the northern hemisphere mid-latitudes in places such as southern Europe (Bari et al., 2004), Italy (Amaducci et al., 2008 and Consentino et al., 2012), the Netherlands (Van der Werf, 1994), Hungary (Bosca and Karus, 1998), China and Europe (Amaducci et al., 2014), and the American states of Oregon (Karow et al., 2013) and North Dakota (Kraenzel, 1998). These places share similar mid-latitudes and in most places share common physical features with West Virginia such as a mountainous region, which assists in identifying factors critical to hemp cultivation in the Appalachian region.

Industrial hemp not only provides vital components for hemp-based commodities; it also provides the raw material inputs which are imported from foreign countries and sold for use in American manufacturing for various consumer commodities. Hemp cultivation can help boost the economy in a variety of ways because “hemp fibers are used in a wide range of products, including fabrics and textiles, yarns and spun fibers, paper, carpeting, home furnishings, construction and insulation materials, auto parts, and composites” (Johnson, 2015). The benefits of hemp not only correspond by increasing the economy, but also have an environmental aspect as a counterbalance to ecological degradation.

Hemp Ecology. Cultivating hemp or *Cannabis Sativa L.* may be a very viable indigenous way to merge the two aspects of society, the economy and the environment, actively cooperating for mutual sustainable benefits. Hemp fiber production may have the potential to revolutionize the economic choices for both rural and urbanized areas with increased economic development opportunities from the cultivation of this natural fiber because of the tertiary economic opportunities provided by harvesting, transporting, and processing fibers into processed goods.

The cultivation of hemp fiber may also mitigate several environmental degradation concerns such as soil erosion, nutrient replenishment, and soil contamination by bolstering soil remediation efforts by having several positive benefits for creating a sustainable environment. The ecological benefits of cultivating industrial hemp have been documented by the NOVA Institute. Piotrowski and Carus have detailed the different ecological benefits of hemp cultivation in their 2011 circular. Hemp cultivation performed in a crop rotation is beneficial for the soil's fertility because of the deep root structure aerating the soil, slowing soil erosion, and if left to fallow, contributing to the field's fertility by returning the nitrogen. Hemp cultivation could potentially improve the fertility of the soil in order to prepare other crops.

Piotrowski and Carus (2011) cited another ecological benefit of hemp cultivation is the reduction or elimination of the need for pesticides, fungicides, and herbicides in its cultivation. These added benefits of hemp cultivation could help naturally reduce the need for artificial fertilizer. Hemp cultivation requires very little effort and can have positive environmental effects by not having to depend upon artificial chemicals to enhance growth.

Piotrowski and Carus (2011) state that hemp is a pioneer plant. This means that this plant will grow in areas that have been devastated by natural and human error-based ecological disasters. Hemp as a pioneer plant prevents further soil erosion and site degradation. More importantly as noted by Linger et al. (2002), hemp may prove to be able to remediate land devastated by heavy metal pollution called phytoremediation. *Cannabis Sativa L.* phytoremediation quality is especially important for the state of West Virginia which has several distressed polluted rivers and streams because of acid mine drainage contamination derived from mining operations. This study has shown that hemp could possibly help remediate the soil and make areas more viable for further agricultural development. Linger et al (2002) phytoremediation research is the basis of the contamination layer from which further research may be performed. Linger et al (2002) concluded that determining the "overall quality of the hemp fiber was not affected by heavy metal contamination," but is not suitable for human consumption and is more suitable for industrial purposes and power generation efforts in the rural areas of the state. The acid mine drainage contaminated hemp material falls below restrictive levels allowing it to be used for power generation.

Industrial hemp is an agricultural crop that has demonstrated great potential for many varied uses, not only in agricultural settings, but in industrial settings as well. The economic and environmental potential has been researched in other parts of the world. Several European countries and regions are using suitability analyses determining whether or not an area could support industrial hemp fiber cultivation to increase their industrial applications. In comparison, the drive has been slow in the United States to accept and legalize the cultivation of American industrial hemp; although hemp for American manufacturing is imported from European and Asian nations. One American suitability study determined whether or not Indian sunn hemp, a distant cultivar cousin to *Cannabis Sativa L.,* has the capacity to grow in the American southeast as a cover crop during the winter months to protect against soil erosion and enriching the soil for other crops (Mansoer, 1997). In fact, the use of sunn hemp was endorsed by both the United States Department of Agriculture (USDA) and the Natural Resources Conservation Service (NRCS) in the technical note Sunn Hemp: A Cover Crop for Southern and Tropical Farming Systems specifically citing these ecological benefits of Sunn Hemp cultivation. (USDA and

NRCS, 1999). *Cannabis Sativa L*. has been proven to be like its cultivar cousin sunn hemp by preventing soil erosion because of the root structure which prepares the soil physically and nutritionally for winter cereal crops after harvest (Amaducci et al., 2008).

Hemp fiber cultivation can have additional ecological benefits weaved into the different industrial applications as economic benefits. For example, an indirect ecological benefit of hemp cultivation for the use of fiber processing is paper production (Olev et al., 2005) and (Van der Werf et al., 1994), thereby reducing the need for the cutting of ecologically valuable forests. Hemp cultivation may help prevent deforestation, soil degradation, and preserving major carbon sinks. “Carbon sinks are ecosystems, [which] store carbon dioxide in water sediment, wood, roots, leaves and the soil” (Haris, 2013). The rate of growth of trees and the seasonal cultivation of hemp fiber biomass varies greatly because hemp cultivation occurs in months and sometimes with two or more harvests, while tree growth requires years, making hemp cultivation a renewable source for carbon sequestration. Hemp cultivation may directly become a carbon sink “through photosynthesis, in which the vegetation cover can store a significant amount of carbon dioxide as organic carbon” (Haris, 2013). Therefore the cultivation and use of hemp fiber substitutions for paper and wood products may have additional hidden environmental benefits, not directly related to the cultivation of hemp.

Industrial grade hemp fiber usage has been a major source of scholarly attention concerning possible economic uses involving commodity development. One such economic use is the resumption of textile production (Clarke, 2010) for the consumer market with commodities made from West Virginia cultivated hemp and processed by West Virginia workers. Hemp also has some industrial applications such as industrial components for composite production (Wallot et al., 2012) and other industrial applications, (Ranelli and Venturi, 2004) agricultural uses as a natural feed and bedding for livestock, (Karus and Vogt, 2004) hemp-based thermal insulator that can be utilized as an organic insulator, (Zampori et al., 2013) and for hemp lime wall constructions (Ip and Miller, 2012). As these are products that are either indirectly or directly related to human usage or consumption the inherent quality of the fiber should be evaluated for any possible harmful contamination that may be present. The quality of hemp fiber is of the upmost importance and possible contamination factors should be evaluated through the soil quality sampling and testing before cultivating hemp.

Hemp also has another major industrial application that deserves to be evaluated separately, as a means of energy production. Hemp has also received academic research into the viability as a possible alternative sustainable energy source. Finnan and Styles (2013) researched hemp compared to other biofuel sources such as sugar beets, indicating that fertilizer would be needed to produce a quality energy source. A study conducted by Prade et al (2011) showed that “two harvest periods for an optimal energy yield were found in September-October for biogas yields and February-April when used for solid fuel as being comparable to other energy crops.” Additionally, Prade et al. (2012) compared hemp fibers net energy yields and energy outputs to input ratios to other sources of biofuel in Sweden. Prade et al. (2012) concluded that “hemp is an above average energy crop with a large potential for yield improvements.” Developing countries such as Pakistan are researching the possibility of utilizing hemp as a possible biofuel source to meet the energy demands from their growing industrializing economies and population (Rehman et. al., 2013). Burczyk et al. (2008) researched *Cannabis Sativa L.* energy production potential by burning hemp hurds and biomass waste in husk generators.

Hemp attributes such as its physical characteristics help make it a possible energy source. The biomass potential of the plant is dependent upon the environmental conditions affecting its growth. “The role of fibre hemp is also growing because as a non-food crop for biofuel production fibre hemp is a great source of cellulose” (Consentino et al., 2012). Hemp cultivation and processing could have a significant positive impact on local economies and increasing the economic growth potential for the state of West Virginia. James Duke (1983) in his *Energy Crop Handbook* observed that “in India, plants remaining in the field after harvesting for fiber are allowed to set seed.” This dual use for these hemp suitable areas involving hemp seed production as well as fiber cultivation only increases the energy capability of using hemp for energy production in areas that were coal extraction sites.

Agronomy. A general assumption was that hemp cultivation areas would be plentiful in West Virginia because of the favorable climate and existing vegetation cover, which has proven not to be the case. Several different sources were consulted when researching the agronomy of hemp grown for fiber production. One such source is an internet source known as Plants for a Future, which details the basic agronomy of *Cannabis Sativa L.*: “it requires a mild temperate climate” (Plants for a Future, 2014). Another academic hemp researcher is Dutch scientist, Dr. Van der Werf, whose research has been focused upon European hemp cultivation. Another trustworthy source is Dr. Bosca, who is a Hungarian hemp researcher with experience in cultivating different hemp cultivars. Hungary, like most Eastern European countries, resides in cooler climate zones lacking the ability to grow cotton fibers for clothing and other items. Another authoritative source provided by Purdue University, is James Duke’s *Handbook of Energy Crops,* which lists *Cannabis Sativa L.* fiber and seed production as sources of biofuel as an energy producing crop.

Climate is an important aspect to any agricultural suitability analysis, since hemp is a plant that requires certain climate based conditions for successful cultivation. Climate is defined as the “state of the atmosphere for a given place over time” (Rohli and Vega, 2015). Geographic regions are often classified into different climate zones depending upon two major parts, temperature and precipitation. These two major factors usually differ in frequency and intensity depending upon physical factors such as composition, height, and location of the physical terrain interacting with prevailing atmospheric conditions.

However the state's latitudinal position has several important roles in the development of temperature. The first role is "because it affects the sun angle of a location, which in turn affects the intensity of radiation received at the surface, which in turn affects temperature" (Rohli and Vega, 2015). The second role is the length of daylight hours and the emergence of seasonal variability. Rohli and Vega (2015) state that "The greater number of hours of daylight, the more time exists for the surface to heat up." The further the latitudinal position from the equator, on which the sun shines directly and has equal hours of daylight and night, the more or less solar radiation a location receives in a year. West Virginia's latitude is directly in the mid-latitudes, which commonly has periods of daylight exceeding 12 hours during the summer growing season. This factor was further explored by evaluating the variables of temperature, growing degree days, and aspect.

The first major climate factor affecting hemp cultivation is temperature. For fiber cultivation climatic considerations Van der Werf recommends:

> For fiber production "breeding late-flowering hemp seems a promising strategy to improve the stem yield potential of hemp. Hemp grows at low temperatures, its base temperature is 1 °C for leaf appearance, and 2.5 °C for canopy establishment" (1994).

The same sentiment is expressed by the website Plants for a Future by stating that hemp requires "an average annual temperature range of 6 to 27°C" (Plants for a Future, 2014). However according to Bosca and Karus (1998) *Cannabis Sativa L.* "optimal growth temperatures are between 19 and 25 ° C (66 - 77° F)." Hemp exhibits a high tolerance for colder temperatures, so any warmer temperatures at the base 1 °C will only increase *Cannabis Sativa L.* growth as determined in each climate region's total amount of growing degree days.

Along with both the maximum and minimum temperatures taken from a location each space has an average temperature. Growing degree days (GDD) are used in agricultural suitability studies to show the growth potential of an area's capability to climatically support the vegetation. Bosca and Karus (1998) state that "Fiber-hemp plants require a total heat over the growing period of 1,900-2000 GDD_c (3,400-3600 GDD_f) from germination to technical maturity (110-115 days) and 2,700-3000 until seedlings develop." James Duke (1983) in his *Handbook of Energy Crops* states that hemp is "Generally sown in March, seeds germinate at low temperature, but not below 1deg.C. Rate of seed sown varies with type of fiber desired; for coarse fiber for cordage and coarser textiles, 2.5 bu/ha is used; for finest fibers, 7.5-10 bu/ha [is] used." The finer the fabric produced in the final product means that more bushels of hemp are required per hectare.

Precipitation is the other major climatic factor in any crop cultivation. Plants for a Future website indicates that "cannabis is reported to tolerate an annual precipitation range of 30 to 400cm" (Plants for a Future, 2014). Precipitation requirements for hemp is confirmed by Bosca and Karus, state hemp cultivation necessitates "500-700 millimeters (20-28 inches) of precipitation, or an adequate quantity of water" (1998). Bosca and Karus (1998) also state that during the vegetative phase of growth that at "least 250-300 millimeters (10-14 inches)" is needed for successful hemp fiber production. However once firmly established hemp's complex root structure better utilizes water within the soil as long as it's not obstructed by the water table, bedrock, and /or hardened soil. *Cannabis Sativa L.'s* central root structure grows deep preventing topsoil erosion by reaching "depths of 2-3 meters (6.5-10 feet)" (Bosca and Karus, 1998). Hemp's deep root structure is a major reason why hemp prevents erosion and increases soil stability in previously unstable barren areas.

The required soil composition for "Cannabis thrives on rich, fertile, neutral to slightly alkaline, well-drained silt or clay loams with moisture retentive sub soils, it does not grow well on acid, sandy soils" (Duke, 1983). The soil assessment provided by Bosca and Karus (1998) agrees with Duke by stipulating by type of soil that

> "the soils with the highest yield are the primarily ones that have developed on loess: very rich black soils (mollisols) degraded black soils, brown rendzina soils and brown steppes soils. These soils have a favorable water balance, good water permeability and an excellent nutrient accumulation potential. The "brown" soils and the transitions to black soils are also suitable, provided the soil is deep enough."

The soil's basic composition classification helps determine hemp fiber suitability. Bosca and Karus state that the "suitable soils for hemp cultivation are found in mountainous regions and low mountain ranges (different types of brown soils, and rendsolls, a variety of mollisols)" (1998). This soil classification is required because hemp is very water sensitive and an excess of water leads to several fungal diseases, which will destroy the hemp crop. So the area not only has to possess the right soil composition, but it must be properly drained for successful hemp cultivation. This fact shows the importance that the physical terrain has in a successful hemp fiber cultivation venture.

Industrial hemp cultivation does have some terrain limitations associated with it. Hemp can be grown at various altitudes, but the final outcome, hemp fiber quality, may be different. Hemp grown in higher altitudes will have more seed production than quality fiber production. Bosca and Karus state that the best hemp is grown at "sea level to 400 meters or 1,300 feet" (1998). Some of the major problems associated with hemp cultivation at higher altitudes or elevation are that "at higher altitudes, technical maturation and the drying process is at risk" (Bosca and Karus, 1998). The limits of altitude were given various tests in 2003 and 2004 in France and showed that hemp cultivation and quality can be preserved upwards towards 1000 meters (Bouloc et al., 2013). Therefore, sea level to 1000 meters will constitute the limit applied to West Virginia altitude or elevation for adequate cultivation of hemp fiber.

The next important terrain variable is the terrain's slope. Several factors were considered when determining the physical terrain slope adequate to cultivate and harvest hemp fiber. One factor is that commercial stakeholders consider slopes over 35° are not feasible to farm due to problems harvesting the product. (Cesonoma, 2013). The defining slope factor for effective hemp fiber cultivation is that farmers should use a slope not exceeding 5%. This stricter slope restriction occurs because "if the slope is greater than 5%, precipitation runs off the field" (Bosca and Karus, 1998). A detriment to hemp fiber cultivation occurs because too little slope can create standing water, which leaves the hemp fiber crop vulnerable to several damaging fungal diseases. A 5% slope will be considered for West Virginia as adequate for hemp fiber cultivation.

The amount of sun the plant receives or the aspect of the terrain is important for hemp fiber cultivation and helps determine the amount of GDD for the region. Hemp is a very photosensitive plant “Hemp is a short-day plant: flowering is hastened by short days and delayed by long days.” (Van der Werf, 1994). Since hemp cultivation is very photosensitive, the amount of sunlight must be determined to identify when the plants begin to flower and time for harvest. Bosca and Karus state that “it is important that fields face south” (1998). The basic geographic principle of location becomes an important indicator for the success of hemp cultivation as the favored aspect will be from the south.

Hemp should be grown in cultivated beds and is grown in high densities, which also helps with weeding out the bed since hemp naturally does this to other competitor plants. Duke (1983) states that hemp “Plants require little cultivation, except for weeding during early stages of growth. Hemp grows rapidly and soon crowds out weeds. After plants are 20 cm tall, weeding is abandoned.” This practice is done on purpose because “hemp is grown at high plant densities to improve stem quality and to increase the allocation of above-ground dry matter to the stem” (Van der Werf, 1994). Not only is the plant grown in high densities but it is grown to great height, according to Duke (1983) because “usually the taller the plant, the longer will be the fiber with a greater yield per plant.” Forested areas are eliminated from any land use land cover (LULC) classification because hemp cannot be effectively cultivated under a forest canopy.

Industrial hemp exhibits a rapid growth rate and combined with the long root structures helps prevent weed infestation in a field. Hemp has very few pests; very little if any pesticides have to be deployed thereby reducing cultivation costs and possibilities of chemical contamination when processed for consumer use. However as with all crops hemp does require a little fertilization to be a successful crop. Duke (1983) states that hemp requires some fertilization by using “Chalk, potash, or gypsum may be applied to the soil to add the needed nutrition. Sodium nitrate and ammonium along with potassium sulfate have a beneficial effect on the fiber crop. Fiber-producing plants should always have plenty of proper nutrients, especially nitrogen, which is the most important element needed.” Hemp returns much of the fertilizer back to the soil when used as a ground cover crop.

The climate of the region is the most important factor in determining the optimum growing conditions for hemp in West Virginia. The state’s climate will be analyzed using an eighty-year period broken into thirty-year increments to determine whether or not West Virginia climatic trends are suitable for hemp fiber cultivation. A soil analysis will occur by reclassifying soil attributes into one soil suitability shapefile possessing the specified soil composition and drainage patterns. The physical features of the mountainous region with terrain analysis variables such as elevation, slope, and aspect will be added to determine the West Virginia hemp fiber cultivation suitability. The variables for hemp fiber basic agricultural suitability are elevation, aspect, slope, minimum and maximum temperature averages, growing degree days, precipitation averages, soil composition, and drainage attributes to determine the areas where industrial hemp fiber cultivation can be potentially established successfully according to the agronomic standards.

CHAPTER THREE

METHODOLOGY

Planning. Sustainable development must first be defined by looking at what does it mean to have sustainability. One definition from the Environmental Protection Agency (EPA) defines sustainability as "based on a simple principle: Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment. Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations" (EPA, 2013). Following similar thoughts close to the EPA, a business definition of the concept does not vary much from the EPA's definition as in stating, "The maintenance of the factors and practices that contribute to the quality of environment on a long-term basis" (Business Dictionary, 2013). Berke et al. (2006) states in regards to planning that the most "widely used definition of the concept is taken from the 1987 report *Our Common Future* from the United Nations World Commission on the Environment and Development (WCED) as 'Sustainable development is the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.' " Environmental sustainability is the assessment of the current environmental factors of an area, seeking to either maintain or improve the overall quality of the environment for present and future generations through the differing types of land use policies utilized by the planner in their comprehensive plan.

Environmental sustainability or sustainable development within planning is not a new concept, but rather the crux of the discipline. In fact, modern planning owes its existence to the environmental impacts of the unsanitary conditions and squalors that characterized American cities at the beginning of the 20th century as a byproduct of the American industrial revolution from which the practice of unregulated land use led to unsanitary development. In response to the industrial revolution squalors planning was conceived first as the City Beautiful Movement characterized by Chicago in the 1893 Columbian Exposition (Berke et al., 2006). Recovering from its near destruction from the Great Fire in 1887, Chicago represented the heights which cities could attain when properly planned. The federal American government in response to media inspired social protest conferred legitimacy and authority to the states and local regions to institute and foster planning as a formal academic discipline and validated through the rule of law. Planning's first and major concern is maintaining and/or protecting an area's environmental assets from being destroyed by unregulated land use development.

Planning first began to employ the newest sciences of the day to the landscape by using systems theory, which used the scientific process and rational observations alone to base development decisions (Allmendinger, 2009). Systems theory views a region through various linked physical and social processes and their interactions with each other. The concept of environmental sustainability is sustained by system theory planning because of the various scientific data observations as a foundation to construct environmentally sustainable land use development decisions molded by the physical geography of the area, while allowing the identification, classification, and clustering of various business enterprises. However systems theory alone fails because it only projects the empirical facts as observed by the observer, without any moral based ethical imperative (Allmendinger, 2009). In essence both economic and environmental systems are equally valid and vying for dominance of land use development or conservation. Accordingly planners became the de facto judge determining which system would be conserved, developed (or disturbed) for the benefit of the current and future residents (Allmendinger, 2009).

Planners were criticized because of the increasing socio-economic pressures from private stakeholders such as businesses and lobbyists permitting economic development to trump environmental sustainability. In response to these criticisms, planning methodologies transformed into what is called advocacy planning. Envisioned by Paul Davidoff during the 1960's, advocacy planning allowed the concerns and issues of residents to have equal weight of political and economic interests by introducing the concept of social justice (Allmendinger, 2009). Land use planners became an advocate speaking for those who do not have any political power or economic influence over future developments. Disadvantaged groups ranged from the rural poor to a personified physical environment, which possesses neither any voice nor legal standing (Allmendinger, 2009). Planners and their planning processes became more open and communicative with the attitude of exhibiting more openness, accessibility, and willingness to hear and consider all constituents' concerns or complaints.

Planning does help serve the dictates of the economy and the source of its legitimacy as advocacy planning gave way to neo-liberalism, which convalesced because of direct government influence over the economy in the 1980's (Allmendinger, 2009). Neo-liberalistic planning has a negative relationship with environmental sustainability because land use was only to maximize the economy by producing as many financial transactions as quickly and as many as possible, giving rise to the mass consumerism noted in advanced capitalistic nations (Allmendinger, 2009). The sustainability of the land is not defined in environmental capacities, but rather strictly through simplified zones of economic development and transaction completions.

Planning once again found itself needed as the effects of mass consumerism created more pollution and inhospitable living areas. The 1990's and modern planning reigning methodology then evolved into what is called collaborative planning (Allmendinger, 2009). Collaborative planning uses communicative theories and rationality seeking to find a balance between powerful political, economic influences and those residents being planned (Allmendinger, 2009). Adapted from both planning paradigms, systems theory and advocacy planning, the key points for collaborative planning are listening, education, and developing the ways and realizing that the optimum plan may have to be re-considered within the current political and economic situations and taking small steps to achieve goals (Allmendinger, 2009). In essence, the planner became the touchstone for every stakeholder and the general public by virtue of the communicative process, a key point in advocacy planning theory. Communicative planning theory has the strengths of system's theory by being supported by scientific data and communicated cartographically through using geospatial analysis methodologies and geospatial information systems (GIS) producing a comprehensive development plan in a more transparent and democratic way.

GIS And LUCIS. GIS is the way a planner or any researcher can produce visible results; it can effect change by fully analyzing a geographic or social region in terms of environmental stability. "GIS is an information management tool that helps store, organize, and use spatial information in form that allows everyday tasks to be completed more efficiently" (Falconer et al., 2002). GIS is a powerful tool from which planners and physical scientists can monitor environmental conditions and provide feedback to involved stakeholders. "Contemporary land suitability analyses use computer based mapping on GIS software to compute the overlay and numerical calculation procedure" (Berke et al., 2006).

One such GIS based methodology is called LUCIS or known as the Land Use Conflict Identification Strategy. LUCIS is the Florida State University Geography Department planning approach which identifies areas that are suitable for development and areas of conflict according to stakeholder preferences and geospatial science. LUCIS was developed for "students from the departments of landscape architecture and urban and regional planning and derived from the work of Eugene P. Odum, one of the 20th century's foremost ecologists" (University of Florida, 2014). The traditional LUCIS model has three categories from which the physical and human interactions are geographically classified: agricultural, conservation, and urban.

The LUCIS model has five distinct goals involved in the pre-planning criteria and important in the classification of the site data.

The goals of LUCIS development described on the University of Florida's website are:

"1.) Define goals and objectives that become the criteria for determining suitability.
2.) Inventory data resources potentially relevant to each goal and objective.
3.) Analyze data to determine relative suitability for each goal.
4.) Combine the relative suitability's of each goal to determine preference.
5.) Compare the ranges of land-use preference to determine likely areas of future land-use conflict" (2014).

LUCIS' importance is based upon its classification system. "In the higher orders of the LUCIS hierarchy suitability assignments are made for the development of land uses (i.e., agriculture, conservation and urban) which are then combined in a single raster to identify the conflict between land use preferences" (Arafat et al., 2010). The three LUCIS layers are modified more fully reflecting the goal of the study, finding suitable hemp cultivation sites capable of producing quality hemp fibers. The first layer is the raw agricultural layer of the physical attributes which influences an area capacity for hemp cultivation. The agricultural layer has two parts which are ultimately joined together producing the raw agricultural output for West Virginia. The first part of the agricultural layer is terrain based factors such as elevation, slope, sun exposure aspect, soil composition and drainage. The second part of the agricultural layer utilizes climatic factors such as temperature (minimum and maximum averages), precipitation, and growing degree days, which have been outlined in the agronomy of hemp. The second LUCIS layer is the urban layer, which details the land use and land cover classification for the entire state of West Virginia. The third LUCIS layer instead of conservation has been termed contamination to reveals the areas of suitable hemp cultivation that are in conflict with areas affected by acid mine drainage, a major source of contamination for the state and detrimental to the quality of the hemp fiber as a finished product.

The methodology utilizing geospatial science and GIS software produces the results in a visual representation which is basically understood as follows:

> "The concept that underpins land-use suitability modeling (and cartographic modeling in general) is map algebra. Map algebra processes maps (spatial data layers) as variables in algebraic equations. While in algebra variables are represented by symbols such as x and y; in map algebra the entire maps represent the variables (that is, attribute values associated [with] a set of map objects such as rasters or polygons represent a variable in map algebra)" (Malczewski, 2004).

A suitability analysis can perform a comparison on these variables by utilizing the sublayers of vector data and raster data are merged together in a vector overlay model. The first two layers will be raster calculated to give a general area. The urban output will utilize this formula:

(Agricultural Layer) * (Urban Layer) = (Hemp Sites Areas Layer)

The urban output will be vectored using the raster to polygon tool. It is the goal to precisely define the sites by filtering the areas through major stakeholder concerns, impervious object, unfavorable physical features, road networks, or territory using vector shapefiles like a chisel to reveal the true form of the site. The third major layer instead of being conservation is instead contamination to answer the third question proposed. Acid mine drainage will be given physical geographic area besides a stream by using watersheds. The modified hemp sites are then layered using vector overlay to reveal the areas possibly contaminated by acid mine drainage.

The major rule governing the combination of spatial data in this study is the dominance rule. "The dominance rule depends upon the selection of a single value (the dominant value) that is preferred over all values found at the same location. The selection is defined or governed by external rules not just the combination of values" (Carr and Zwick, 2007). The type of dominance rule used is called exclusionary screening or sieve mapping from which different features are added or subtracted from the region based upon hemp cultivation suitability and/or stakeholder preferences. Sieve mapping standards both in common practice and adopted as the rule of this study are as follows: "spatial datasets are subjected to a query that results in a binary output where 1=true (not excluded) and 0=false (excluded)" (Carr and Zwick, 2007). The selection of the final hemp suitability sites represents a very strict interpretation from the dominance rule, since the final output does not have variable components accounting for the micro climates partly due to physical terrain's specific attributes.

Model Variables. The study's objectives chosen to answer the three main questions were relied upon in the production of three separate geospatial outputs by using ArcGIS 10.1 for tasks, such as image overlay, map algebra and reclassification, while reflecting the LUCIS model categories of agriculture, urban, and conservation (ESRI, 2014).The raster derived areas were combined in a vector overlay model as a sub development layer identifying the basic areas of hemp cultivation suitability agriculture, urban, and contamination. Each output contributes to the functioning of the model as a whole reveals the areas where hemp fiber cultivation may occur showing to what extent an environmentally friendly consumer product may be reasonably obtained. Identifying potential hemp remediation sites could advance scientific inquiry about hemp's effectiveness at soil phytoremediation of acid mine drainage. This method of remediation may prove to be attractive to large land tract owners, such as coal mining operations, as a least expensive way to operate and maintain soil remediation operation.

The first layer identified climatic trends and physical world geographic capacity for the suitability of the cultivation of hemp fiber farming in West Virginia. In order to help identify the suitable areas climatological concepts were utilized to promote sustainability practices especially in land use planning development. These variables are very important to the entire agricultural study of the hemp fiber cultivation capacity and all agriculture needs suitable precipitation and temperatures for successful cultivation.

The climatology of West Virginia is directly related to its varied physical geography. The climate data (precipitation, minimum temperature, maximum temperature) was retrieved from the National Oceanic and Atmospheric Administration (NOAA) Gridded Climate Divisional Dataset, 46, for the period of 1931-2010 (NOAA, 2015). West Virginia is divided into six different climate zones by the National Climate Data Center (NCDC). The West Virginia climate regions are Northwestern, North Central, Southwestern, Central, Southern, and Northeastern divisions.

The Appalachian Mountains provide orographic lifting mechanism from which the low pressure, moisture bearing wind parcels produce precipitation. The orographic lifting produces higher precipitation levels in the western part of the state, while the eastern half, (leeward side) have a much drier climate exhibiting the rain shadow effect. The temperature in West Virginia is overall temperate with variations being mitigated in the western half of the state by the Ohio River and the cooler regions located in the Appalachian Mountains. The compatibility of the major climatic factors is a crucial factor determining the successful hemp suitability growth potential for West Virginia. Average precipitation amounts and the state's minimum and maximum temperatures were analyzed and evaluated to determine if climatological trends over the last eighty-years are stable or too variable to maintain hemp fiber cultivation as determined by hemp agronomic standards.

Temperature. The overall West Virginia maximum and minimum temperatures were evaluated for an eighty-year period, 1931-2010, and then separated into thirty-year intervals: 1931-1960, 1941-1970, 1951-1980, 1961-1990, 1971-2000, and 1981-2010. By taking the average maximum and minimum average temperatures for this period, the stability of West Virginia temperatures were examined. Each climate division was analyzed and placed into charts. These charts were created by finding the percentage of land area found within each climate division. The total amount of land area was divided into each climate classification division in order to find the amount of land contained in the climate division. This percentage was then multiplied into climate division averaged total for the years: 1931-1960, 1941-1970, 1951-1980, 1961-1990, 1971-2000, and 1981-2010 respectively. The final output was then geographically referenced by climate division and placed into a map for each 30-year increment period and has an accompanying table for the exact averaged temperatures for each division.

Growing Degree Days. Through the analysis of both the minimum and maximum temperatures, West Virginia growing degree days (GDD) were calculated to determine whether or not the state could support hemp cultivation. GDD is "a variable that is accumulated for each degree that the daily mean temperature exceeds some base value" (Rohli and Vega, 2015). The base temperature for *Cannabis Sativa L.* used in the calculation is 1° Celsius or 33.8° Fahrenheit. Additionally if the daily mean temperature does fall below the base threshold, then no GDD are calculated. GDDs are a useful indicator of crop growth and assist the farmer in determining the overall health and maturity of their crops. GDDs do have some basic assumptions made, "that conditions are met adequately, such as precipitation totals, and timing, protection from disease and nutrient availability" (Rohli and Vega, 2015). The GDDs used in this study were not mean daily values, but were calculated upon a much larger scale using the average temperature data from the NCDC for the eighty-year period, 1931-2010. Both the averaged minimum and maximum temperatures were averaged then subtracted from *Cannabis Sativa L.* base temperature (33.8° F) using the formula, **GDD = (Tmax +Tmin)/2 – Tbase**. The averaged GDD was then divided by the number of days of each month for the eighty-year period to produce a general guide of West Virginia GDDs. This output was divided by climate region like temperature maximums and minimums were and cartographically displayed and placed in tabular form. From here the general trend of growing degree days was analyzed and compared to *Cannabis Sativa L*, GDD requirements to produce the final result.

Precipitation. The overall West Virginia Precipitation Normals are shown for the eighty-year period 1931-2010 and separated in thirty-year increments: 1931-1960, 1941-1970, 1951-1980, 1961-1990, 1971-2000, and 1981-2010. Each climate division precipitation graph was calculated by finding the percentage of land area in each climate division. The total amount of land area was divided into each climate classification division in order to find the amount of land contained in the climate division. This percentage was then multiplied into climate division averaged overall eighty-year span into thirty-year increments: 1931-1960, 1941-1970, 1951-1980, 1961-1990, 1971-2000, and 1981-2010 respectively into the chart below. The final output was then geographically referenced by climate division and cartographically displayed for the respective periods. From here the general trend of precipitation was analyzed and compared to *Cannabis Sativa L*, precipitation requirements to produce the final result.

The GIS workflow for the creation of the climatology factors for hemp cultivation using the 1981-2010 data derived from the NCDC data are as follows**:**

> **(Minimum Temperature Shapefile) (Maximum Temperature Shapefile) (Growing Degree Days Shapefile) (Precipitation Shapefile) transformed into rasters using the polygon to raster tool, then using a raster calculation tool (((Minimum Temperature Raster) * (Maximum Temperature Raster)) * (Growing Degree Days Raster)) * (Precipitation Raster) = (WV Suitable Climate Raster).**

This is how the climate portion of the agricultural layer would be displayed through the GIS modeling, but in the case of this model, the climatology analysis revealed that West Virginia had no deficient areas that would affect hemp cultivation by adding it to the agricultural layer.

Soil. Just as the precipitation and temperature in climatology are important to plant growth and success, so are the attributes of the physical landscape's soil important to hemp cultivation. The next area added for analysis is the physical area's major soil type to determine its suitability for hemp cultivation. While evaluating the different West Virginia soil types the drainage capabilities and the soil slope are considered when determining suitability. The data source for the soil attribute layer is a USDA soil shapefile furnished by the Marshall University Geography Department. (Marshall University, 2014). The shapefile classified West Virginia soil into several useful attributes such as major taxonomical groups, soil descriptions, and drainage attributes. The shapefile was copied and two particular factors, soil composition and soil drainage were evaluated and merged together producing one shapefile that had all the criteria that would be transformed into a raster file by using the polygon to raster tool. The soil raster file was then reclassified by labeling areas that did not fit the agronomic standards as 0 and agronomic favorable factors as 1, by using the spatial analyst reclassify tool, into one raster image called the soil suitability layer. The soil suitability layer helped create the first major output, the agricultural layer. The creation of the shapefile followed the GIS function workflow like this:

(Soil Shapefile-Composition) merge geoprocessing tool (Soil Shapefile-Drainage) = (Soil Suitability) polygon to raster geoprocessing tool = (Soil Suitability Raster).

The final result was then reclassified using the reclassify spatial analyst tool into 0 or 1 to determine final soil suitability.

Altitude. The altitude of the area is another physical element that affects the way hemp is successfully cultivated and harvested. Like slope this layer has more to do with the harvesting and cultivation in terms of quality and is more stakeholder preference than a physical limitation. The final limitations of altitude were set at sea level to 1000 meters as prescribed in the agronomic requirements of *Cannabis Sativa L.* Utilizing a digital elevation model (DEM) provided by the West Virginia State GIS Data Clearinghouse (WVGISTC) the altitude of West Virginia was analyzed (WVGISTC, 1999). The DEM was reclassified using the spatial analyst reclassify tool with 0 being false and unfavorable and 1 being true for favorable conditions for hemp fiber growth according to the agronomic standards of sea level to 1000 meters.

Slope. Slope is an important terrain constraint of the Appalachian Mountain dominated state of West Virginia. The terrain feature is very important, especially in the state of West Virginia, which has many mountain features and rolling hills, which could affect the hemp fiber biomass cultivation potential. Slope was derived from the DEM with rule of following the agronomic standard of a slope of five percent slope. (WVGISTC, 1999). Slope is typically calculated using rise divided by run. The DEM's slope was calculated using the spatial analyst slope tool. The slope raster was then reclassified into zero for unsuitable areas and one for suitable areas, so that the most optimum fields with the correct slope best conducive for hemp cultivation may be utilized.

Aspect. Another way of explaining the seasonal temperature variability of West Virginia is the development of an aspect sub layer. Aspect involves taking the variable physical form of the land and projecting how sunlight will shine upon it. Aspect is calculated by using "the compass direction that a topographic slope faces, usually measured in degrees from north. Aspect can be generated from continuous elevation surfaces" (ESRI Help, 2015). The agronomic slope requirement utilized the same DEM previously used for altitude and slope and identified south facing, high sunlight exposure areas (WVGISTC, 1999). The raw slope output was reclassified with the southern aspect using the spatial analyst reclassify tool with the southern aspect as one and all other aspects as zero. After this function all the terrain variables were placed into the raster calculator as such:

((Altitude)*(Slope))*(Aspect) = (Terrain Analysis Raster).

The following raster was then reclassified using the reclassify tool in spatial analyst into the binary 0 or 1 for terrain suitability. The GIS workflow which formed the basis of the agricultural layer using the reclassified rasters in the raster calculator function in spatial analyst is as follows:

((WV Suitable Climate Raster)* (Soil Suitability Raster))* (Terrain Analysis Raster) = (Agricultural Layer).

Current Land Use. The next expected output is the urban layer. This layer reveals the preferences of the different stakeholders for the state of West Virginia in regards to hemp fiber cultivation which includes the following stakeholders: private local landowners, third party interest groups, commercial and industrial developers, state land holdings, federal stakeholders, farmers, new business entrepreneurs, and the private and industrial landowners of previous coalfields. Stakeholder's preferences was derived from the land use and land cover raster (LULC). West Virginia LULC is classified and labelled into 13 different categories. The different categories are defined as follows: 1 - Forested, 2 - Grasslands/Pasture-land/Agriculture, 3 - Barren/Developed, 4 - Open Water, 5 - Mine Grass, 6 - Mine Barren, 7 - Forested in SMCRA Permit Area, 8 - Pre-SMCRA Grass, 9 - Pre-SMCRA Barren, 10 - Pre-SMCRA Forested, 11 - Herbaceous Wetlands, 12 - Woody Wetlands, 25 - Census Roads (WVGISTC, 2012). The categories annotated with SMCRA indicates the sites' land use or cover areas before mining permits were issued and therefore the possibility of acid mine drainage exists. The LULC raster was then reclassified using the reclassify function in spatial analysts. Categories 2, 5, 6, 8, and 9 were chosen as acceptable places for hemp cultivation because the current land use is compatible with agricultural cultivation or preventing disturbing areas of ecological sensitivity. Utilizing hemp agronomical standards along with other conflicting land uses and industrial preferences will be considered narrowing those areas which could support hemp cultivation. Forested areas and wetland areas which could successfully cultivate hemp are not used because these areas either have too thick of a canopy for adequate hemp growth and/or are ecologically sensitive that hemp may destroy indigenous plants' biospheres. The LULC raster was then reclassified using the reclassify function in spatial analysts into 0 or 1 for suitability and placed in the raster calculator and calculated as follows:

(Agricultural Layer)*(Reclassified LULC) = (Urban Layer) which is then transformed using the Raster to Polygon geoprocessing tool becoming (Hemp Suitable Areas Shapefile).

Stakeholder Preferences. The hemp cultivation areas have been identified using raster calculations of the agricultural layer and clarified through a reclassified urban layer through the current LULC. The output from the urban layer is then transformed into a vector shapefile by using the spatial analyst tool raster to polygon tool, so it can be sculpted by major stakeholder preferences more directly. Stakeholder preferences added to the model required the development of a sub-layer mask of the areas which cannot support hemp cultivation and includes the areas affected by either physical features or governmental supervision. This layer was developed into two separate shapefiles one using polygon features and the other using polyline features.

The first merge file is derived from polygons retrieved from WVGISTC included the following: incorporated areas (WVGISTC, 2011a), West Virginia Department of Natural Resources (WVDNR) managed wildlife lands (WVGISTC, 2015), public lands as state parks

(WVGISTC, 2011b), and public lands as federal parks (WVGISTC, 2003) creating a master stakeholder polygon shapefile called merge 1. Merge 1 polygon shapefile was then erased, utilizing the erase tool, from the vectorized urban layer hemp fiber cultivation areas. The result was an effectively sculpting and further defining hemp fiber cultivation areas cartographically, since they were both polygon features. The second merge file contains two polyline shapefiles retrieved from WVGISTC showing roads and railroads (WVGISTC, 2011c) and streams (WVGISTC, 2010) since agricultural crops cannot be cultivated in these inhospitable places. The polyline shapefiles were then combined using a geoprocessing merge tool, thereby creating a master polyline shapefile called merge 2. Merge 2 could not be erased like the merge one shapefile, since polylines are a different feature class than polygons. A different geoprocessing tool, intersect, was utilized to produce the correct visual appearance of hemp fiber suitable sites that were affected by roads and streams further refining the suitable areas. This shapefile permitted the calculation of the area of the site by subtracting the total area in each hemp site by the modified urban layer. The GIS workflow formula for this procedure is a twofold process:

> **(Polygon Merge 1) Erase geoprocessing Tool (Hemp Suitable Areas Shapefile) = (Suitable Hemp Sites)**, **then (Polyline Merge 2) Intersect geoprocessing Tool (Hemp Suitable Sites) = (Hemp Suitable Sites Polyline Mask). The final result of both the polygon extraction and the polyline elimination of roads and streams from within the vectorized raster areas only and thereby creating (Final Suitable Hemp Sites).**

Acid Mine Drainage. To answer the third major question, which of these sites have the possibility of being contaminated, is the last applied model variable, acid mine drainage to create the contamination layer. Valuable minerals such as coal have been "mined in WV since the late 1700's. Active mining has the potential to produce acid mine drainage from high sulfur coal seams and associated strata by exposing the pyrite to water and oxygen" (Faulkner and Skousen, 1998). This layer has a dual purpose because it determines which areas are restricted for hemp cultivation for products for human consumption, and identifies areas suitable for the purpose of hemp-based phytoremediation research for acid mine drainage contamination. The shapefile for acid mine drainage areas was provided by the West Virginia Department of Environmental Protection (WVDEP) directly through an information request (WVDEP, 2014). Since acid mine drainage contamination is discovered through water testing procedures, it follows that watersheds, from which the hemp does grow and receive nutrients and contaminates, drains into the contaminated stream, and may also be affected. The acid mine drainage stream shapefile was expanded by using the Intersect geo-processing tool to identify the hemp cultivation sites in affected watersheds (WVGISTC, 2004). The areas of non-contamination hemp suitability sites were then restricted to the non-contaminated West Virginia watersheds. Just because a contaminated area can grow hemp does not mean that it could not be exploited or processed in other ways such as other industrial applications or even raw energy production using a husk power generator or as production as insulation or hempcrete. The final geospatial workflow was performed like this:

(Final Suitable Hemp Sites) Intersect Tool (Acid Mine Drainage Watersheds) = Contamination Layer.

The vector contamination overlay producing (Final Suitable Hemp Sites) effectively subdivided hemp cultivation into two categories: (Acid Mine Drainage Contaminated Hemp Sites) and (Non-contaminated Hemp Suitable Sites). The two hemp site classification allowed for visual spatial analysis of the incorporated areas within a West Virginia Regional Planning Commission (WVGISTC, 1971). Planners and interested stakeholders might explore how best to invest and utilize hemp cultivation towards the goal of responsible, sustainable development and which of these areas may be possibly used for further academic research of hemp phytoremediation and energy production.

CHAPTER FOUR

RESULTS AND DISCUSSION

The results of this study are three separate outputs which mirror the LUCIS model categories: agriculture, urban, and contamination. When the agronomy of hemp has been established through climatology and properly spatially projected, other conflicting land uses and industrial preferences will be considered narrowing those areas which could support hemp cultivation. Each output represents one category from which it can contribute to the functioning of the model as a whole to reveal the optimum areas where hemp fiber cultivation may occur. Also they are guides revealing to what extent an environmentally friendly consumer product may be reasonably obtained. They could also identify sites that hemp remediation can occur, which would open the way for more scientific inquiry and research about hemp soil remediation. Hemp phytoremediation may prove to be attractive to large tract owners of coal mining operations as a less expensive way to operate and maintain soil remediation operations after mining operations have ceased.

Agricultural Layer

Temperature. The final result revealed that every climate region in West Virginia has adequate temperatures to support hemp cultivation. Hemp cultivation can begin at 1° Celsius or 33.8° Fahrenheit which means that West Virginia has met the temperature agronomic requirements for hemp cultivation. The climatic trend for West Virginia's minimum and maximum temperatures for the last eighty-years show a stable increasing trend, meaning that hemp cultivation and industrial applications have a stable environment to operate and expand the economy. Considering this trend, this layer was not included in the main cartographic output since the climatological analysis of each climate division has assured that the binary output of this layer would be all ones throughout the entire state of West Virginia.

The first NOAA NCDC climate division is the northwestern division. The northwestern climate division comprises the West Virginia northern panhandle. The counties it covers are

Hancock, Brooke, Ohio, Marshall, the Northern part of Wetzel county, western half of Tyler county, Pleasants, Wood, Wirt, and the eastern half of Ritchie County. The temperature trend for this division has exhibited stability, ranging from 40-70 degrees throughout the eighty-year period as evidenced with Figure 2 for the division. The data are also represented in Figure 8 for maximum temperature and Figure 9 for minimum temperature as charts and spatially represented as Figure 10 for the maximum temperature map and Figure 11 for the minimum temperature map. The exact temperature amounts for the division's temperature from 1931-2010 are found in Table 1 for maximum temperature and Table 2 for minimum temperature showing there is a sufficient temperature range to cultivate *Cannabis Sativa L.* according to the agronomic standards.

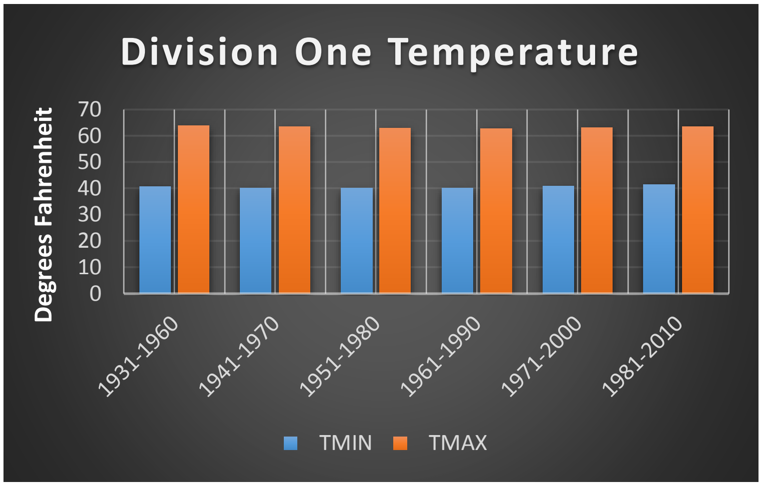

Figure 2 - Minimum and Maximum Temperatures for Division One- 1931-2010.

The second NOAA NCDC climate division is the north central division. The north central climate division comprises the West Virginia counties located right below the northern panhandle. The counties it covers are Braxton, Upshur, Taylor, Barbour, Harrison, Lewis, Gilmer, Calhoun, Doddridge, Marion, Monongalia, the eastern halves of Ritchie, Tyler, and the southern half of Wetzel. The average temperature trend for this division has exhibited stability ranging from 40-65 degrees throughout the eighty-year period as indicated in Figure 3. The data are also represented in Figure 8 for maximum temperature and Figure 9 for minimum temperature as charts and spatially represented as Figure 10 for the maximum temperature map and Figure 11 for the minimum temperature map for the years of 1931-2010. The exact temperature amounts for the division's temperature from 1931-2010 are found in Table 1 for maximum temperature and Table 2 for minimum temperatures showing there is a sufficient temperature range to cultivate *Cannabis Sativa L.* according to the agronomic standards.

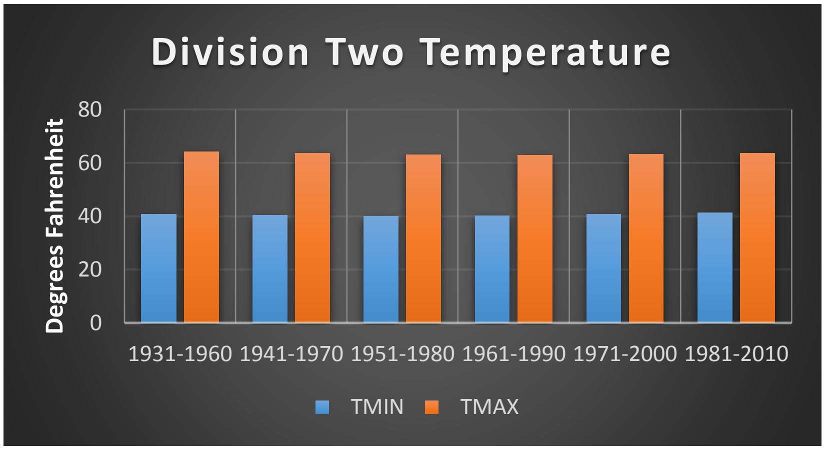

Figure 3 - Minimum and Maximum Temperatures for Division Two- 1931-2010.

The third NOAA NCDC climate division is the southwestern division. The southwestern climate division comprises the West Virginia counties located in the state's far western corner and bordered on the west by the Ohio River. The counties it covers are Mingo, Wayne, Cabell, Lincoln, Logan, Boone, Kanawha, Clay, Roane, Jackson, Mason, and Putnam counties. The average temperature trend for this division has exhibited stability, ranging from 40-65 degrees throughout the eighty-year period as evidenced with Figure 4. The data are also represented in Figure 8 for maximum temperature and Figure 9 for minimum temperature as charts and spatially represented as Figure 10 for the maximum temperature map and Figure 11 for the minimum temperature map for the years of 1931-2010. The exact temperature amounts for the division's temperature from 1931-2010 are found in Table 1 for maximum temperature and Table 2 for minimum temperature showing there is a sufficient temperature range to cultivate *Cannabis Sativa L.* according to the agronomic standards.

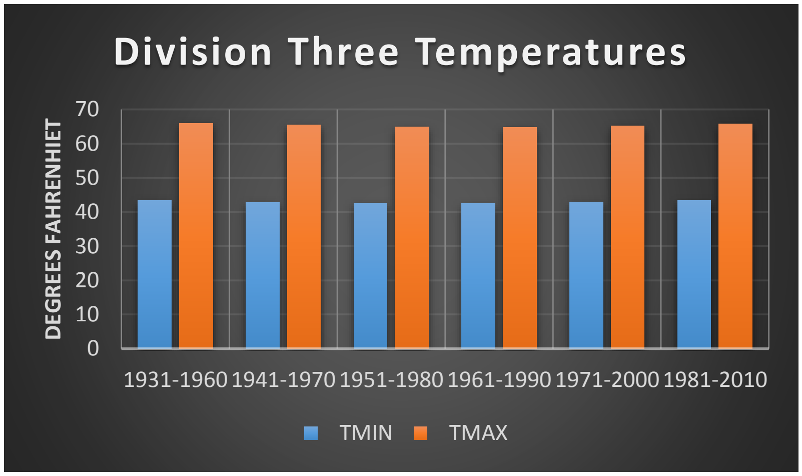

Figure 4 - Minimum and Maximum Temperatures for Division Three- 1931-2010.

The fourth NOAA NCDC climate division is the central division. The central climate division comprises the West Virginia counties located in the state's far eastern corner and has the majority of the state's Appalachian Mountains. The counties it covers are Preston, Tucker, Randolph, Webster, Nicholas, Fayette, Pocahontas, the northern tip of Mercer County, and the western halves of Summers, Greenbrier, and Pendleton Counties. The average temperature trend for this division has exhibited stability, ranging from 38-60 degrees throughout the eighty-year period as evidenced with Figure 5. The data are also represented in Figure 8 for maximum temperature and Figure 9 for minimum temperature as charts and spatially represented as Figure 10 for the maximum temperature map and Figure 11 for the minimum temperature map for the years of 1931-2010. The exact temperature amounts for the division's temperature from 1931-2010 are found in Table 1 for maximum temperature and Table 2 for minimum temperature showing there is a sufficient temperature range to cultivate *Cannabis Sativa L.* according to the agronomic standards.

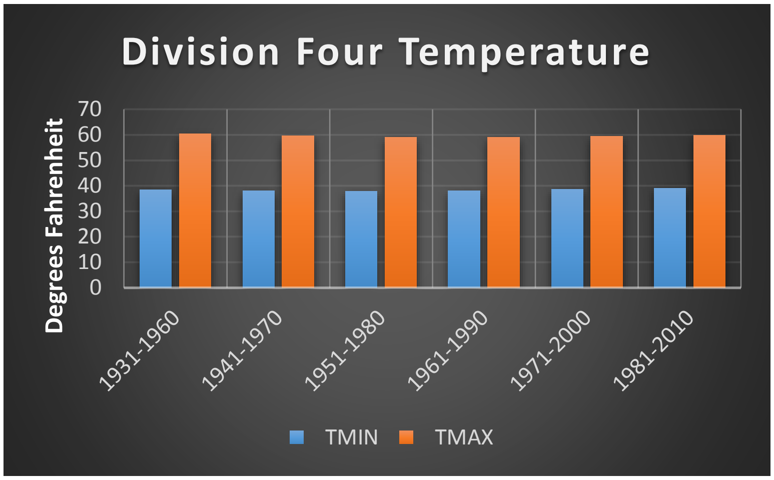

Figure 5 - Minimum and Maximum Temperatures for Division Four- 1931-2010.

The fifth NOAA NCDC climate division is the southern division. The southern climate division comprises the West Virginia counties located in the state's far southern bottom of the state. The counties it covers are Mc Dowell, Wyoming, Monroe, the southern half of Mercer County, and the eastern half of Summers county. The average temperature trend for this division has exhibited stability, ranging from 40-65 degrees throughout the eighty-year period as evidenced with Figure 6. The data are also represented in Figure 8 for maximum temperature and Figure 9 for minimum temperature as charts and spatially represented as Figure 10 for the maximum temperatures map and Figure 11 for the minimum temperature map for the years of 1931-2010. The exact temperature amounts for the division's temperature from 1931-2010 are found in Table 1 for maximum temperature and Table 2 for minimum temperature showing there is a sufficient temperature range to cultivate *Cannabis Sativa L.* according to the agronomic standards.

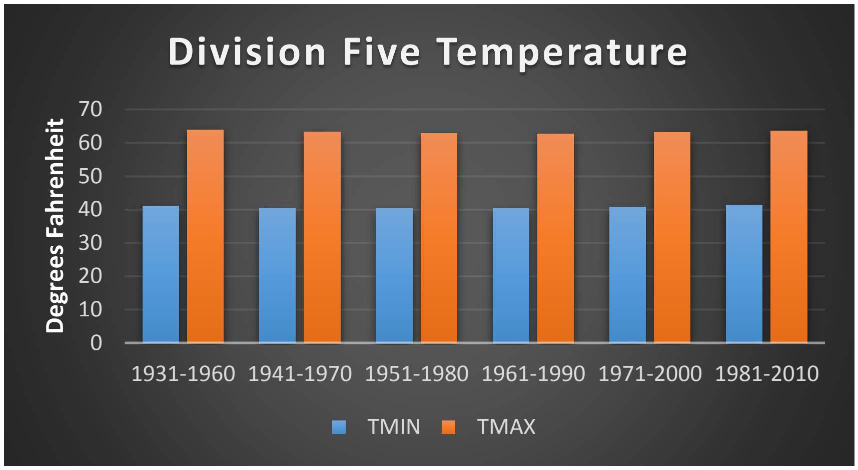

Figure 6 - Minimum and Maximum Temperatures for Division Five- 1931-2010.

The sixth NOAA NCDC climate division is the Northeastern division. The Northeastern climate division comprises the West Virginia counties located in the state's far eastern corner and has the rest of the state's Appalachian Mountains and is bordered by the Potomac River. The counties it covers are Jefferson, Berkeley, Morgan, Hampshire, Hardy, Mineral and the eastern halves of Grant and Pendleton Counties. The average temperature trend for this division has exhibited stability, ranging from 40-65 degrees throughout the eighty-year period as evidenced with Figure 7. The data are also represented in Figure 8 for maximum temperatures and Figure 9 for minimum temperatures as charts and spatially represented as Figure 10 for the maximum temperature map and Figure 11 for the minimum temperature map for the years of 1931-2010. The exact temperature amounts for the division's temperature from 1931-2010 are found in Table 1 for maximum temperature and Table 2 for minimum temperatures showing there is a sufficient temperature range to cultivate *Cannabis Sativa L.* according to the agronomic standards.

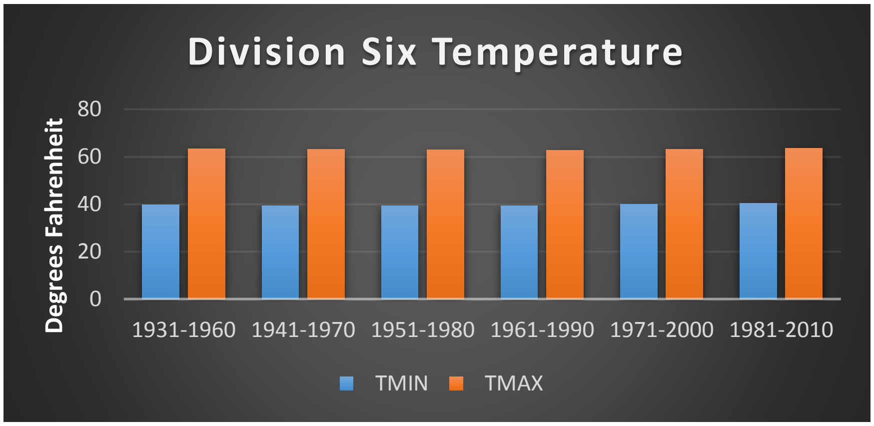

Figure 7 - Minimum and Maximum Temperatures for Division Six- 1931-2010.

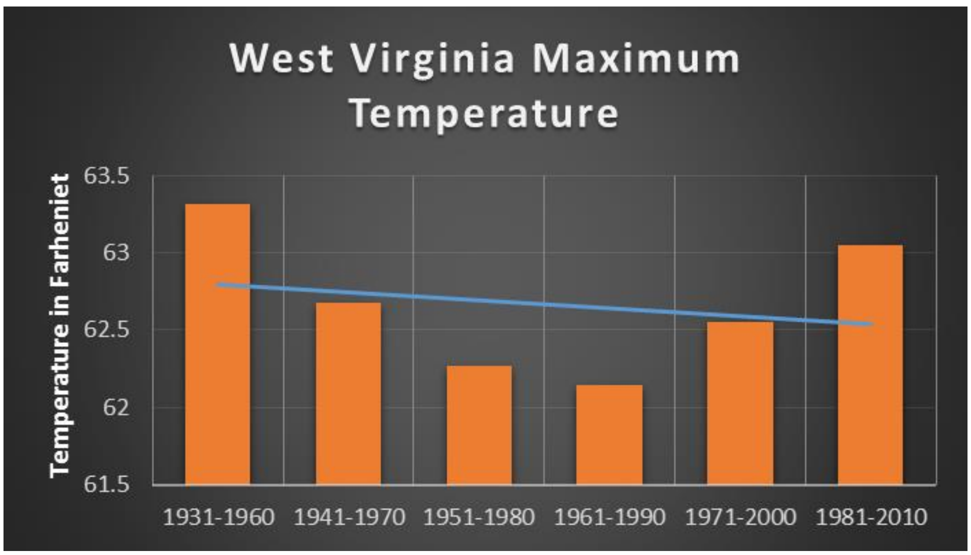

Figure 8 - Maximum Temperatures Totals for West Virginia- 1931-2010.

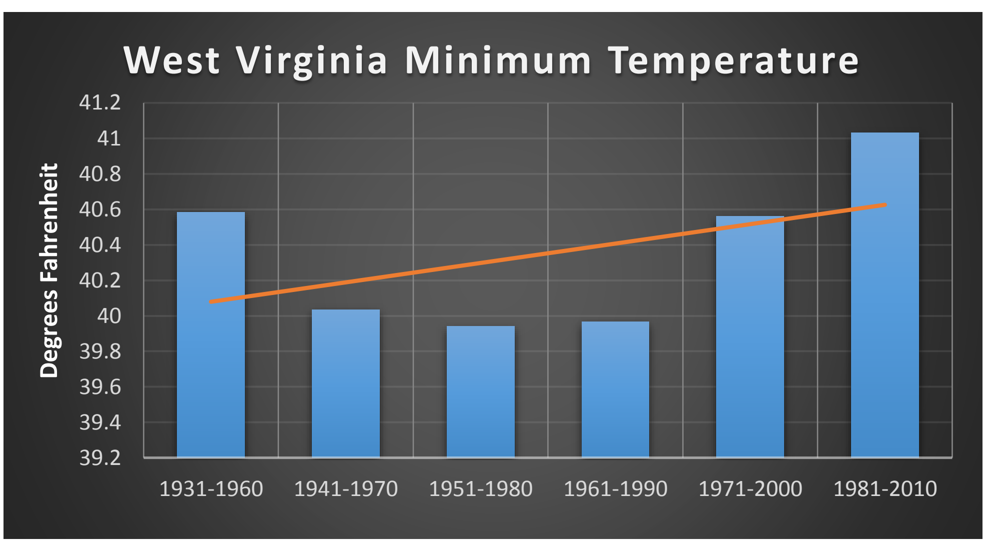

Figure 9- Minimum Temperatures Totals for West Virginia- 1931-2010.

West Virginia Maximum Temperatures 1931-2010

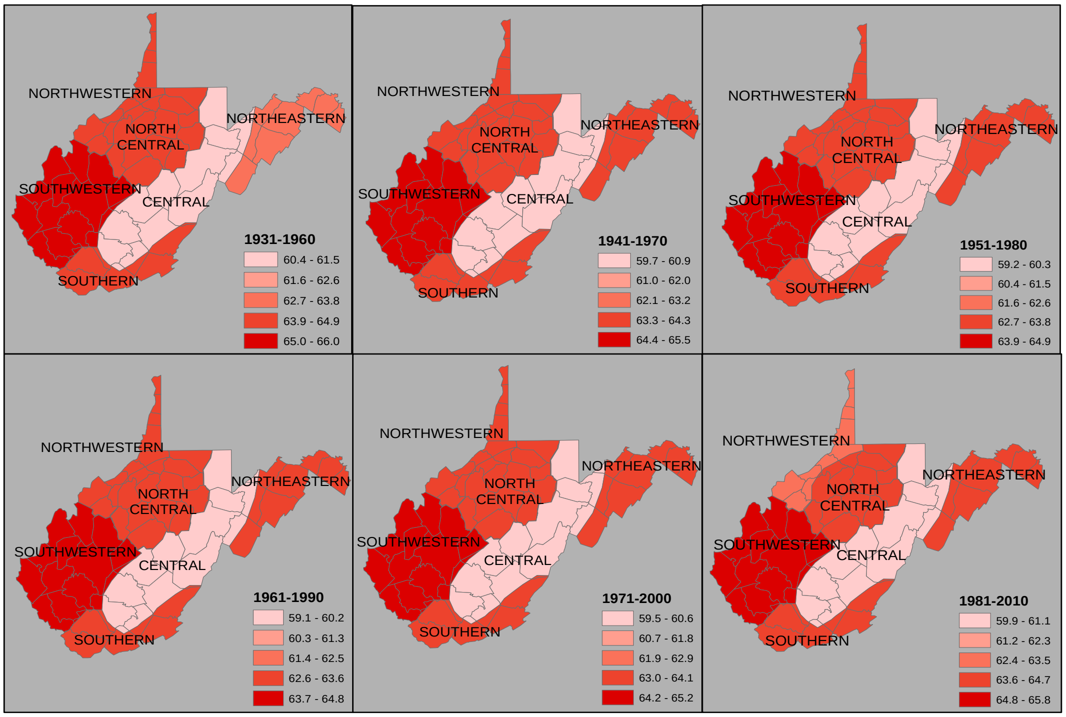

Figure 10 - Maximum Temperatures Totals for West Virginia- 1931-2010.

West Virginia- Minimum Temperature 1931-2010

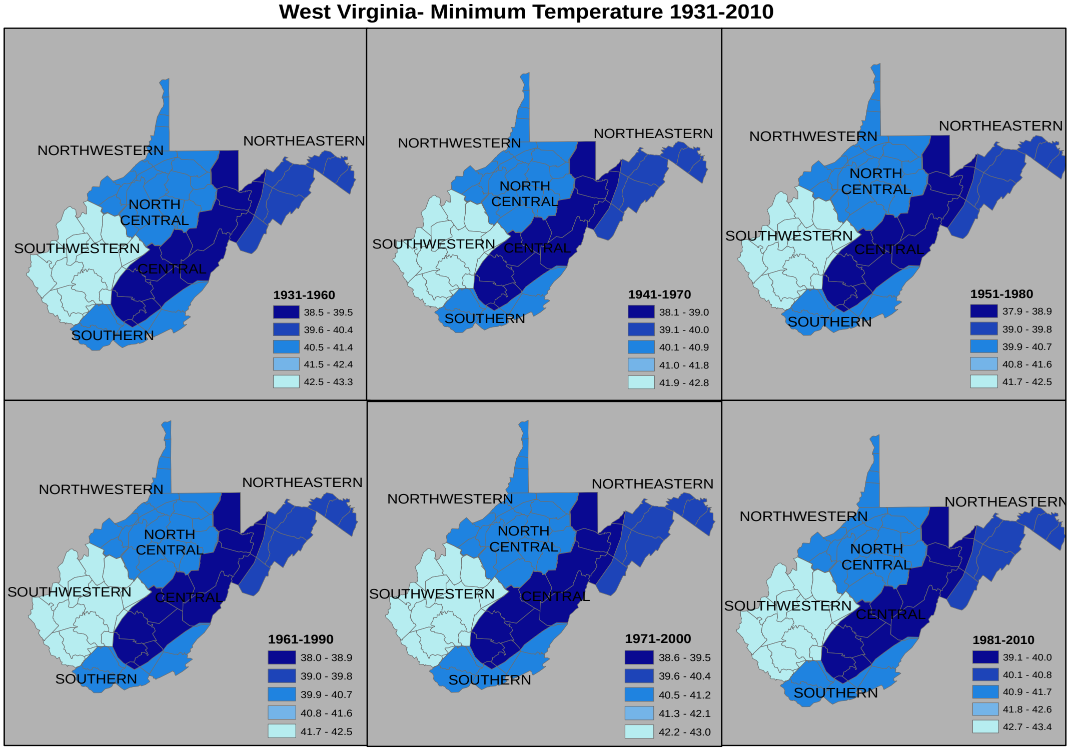

Figure 11 - Minimum Temperatures Totals for West Virginia- 1931-2010.

Table 1 - West Virginia Division Averaged Maximum Temperatures and Total.

West Virginia Division Averaged Maximum Temperatures and Total						
Division	**1931-1960**	**1941-1970**	**1951-1980**	**1961-1990**	**1971-2000**	**1981-2010**
Northwestern	63.81	63.37	62.85	62.73	63.02	63.46
North Central	64.15	63.69	63.12	63.12	63.29	63.77
Southwestern	66.03	65.47	64.91	64.78	65.22	65.83
Central	60.37	59.70	59.18	59.05	59.50	59.93
Southern	63.85	63.27	62.80	62.69	63.11	63.58
Northeastern	63.51	63.22	62.88	62.83	63.25	63.70
Total	**63.32**	**62.67**	**62.27**	**62.14**	**62.55**	**63.05**

Table 2 - West Virginia Division Averaged Minimum Temperatures and Total.

West Virginia Division Averaged Minimum Temperatures and State Total						
Division	**1931-1960**	**1941-1970**	**1951-1980**	**1961-1990**	**1971-2000**	**1981-2010**
Northwestern	40.67	40.16	40.02	40.13	40.84	41.47
North Central	40.72	40.27	40.12	40.15	40.76	41.24
Southwestern	43.33	42.75	42.54	42.46	42.97	43.43
Central	38.51	38.10	37.93	38.00	38.63	39.09
Southern	41.06	40.46	40.24	40.23	40.83	41.35
Northeastern	39.83	39.41	39.39	39.50	40.08	40.48
Total	**40.58**	**40.03**	**39.94**	**39.97**	**40.56**	**41.03**

Growing Degree Days. Using both the average minimum and maximum temperature then subtracted from hemp's base temperature revealed the number of growing degree days required to crow the crop. This chart assists cultivators in determining when to harvest and how many harvests can be accomplished. The climatological studies showed that in West Virginia the number of growing degree days are increasing the overall state and each climate division showed an increase in maximum temperatures and a decrease in minimum temperatures.

Overall the trend has been slowly increasing that has been seen in almost every division with the obvious exception being the northeastern division. The stability of the West Virginia climate as evidenced through the eighty-year period makes it a suitable area for hemp cultivation, especially so as the growing degree days continue to increase. *Cannabis Sativa L.* requires approximately 3,300 growing degree days, which every area in West Virginia, except the central division which has the Appalachian Mountain Range, has enough growing degree days for two different crops of hemp as evidenced cartographically in Figure 12 and the climate region’s exact values for the eighty-year period exhibited in Table 3. The stability of the growing degree days is referenced by the span between both the maximum and minimum temperatures for each thirty-year period was shown in Figures 8 and 9 respectively and spatially in Figure 12, and each division’s exact amounts of GDDs are located in Table 3 for each thirty-year increment of the eighty-year period.

Table 3 - West Virginia Averaged Growing Degree Days from 1931-2010.

West Virginia Averaged Growing Degree Days						
Division	**1931-1960**	**1941-1970**	**1951-1980**	**1961-1990**	**1971-2000**	**1981-2010**
Northwestern	7028.32	6927.46	6842.21	6856.55	6951.36	7096.91
North Central	7065.98	6960.94	6861.94	6851.94	6944.21	7077.78
Southwestern	7781.93	7619.27	7507.44	7484.13	7596.61	7760.24
Central	6106.08	5991.31	5898.79	5907.72	5993.34	6113.65
Southern	7014.20	6859.32	6762.28	6755.70	6862.57	7006.33
Northeastern	6812.33	6738.57	6701.36	6728.95	6829.95	6939.23
Total	**41808.83**	**41096.86**	**40574.03**	**40585.00**	**41178.04**	**41994.14**

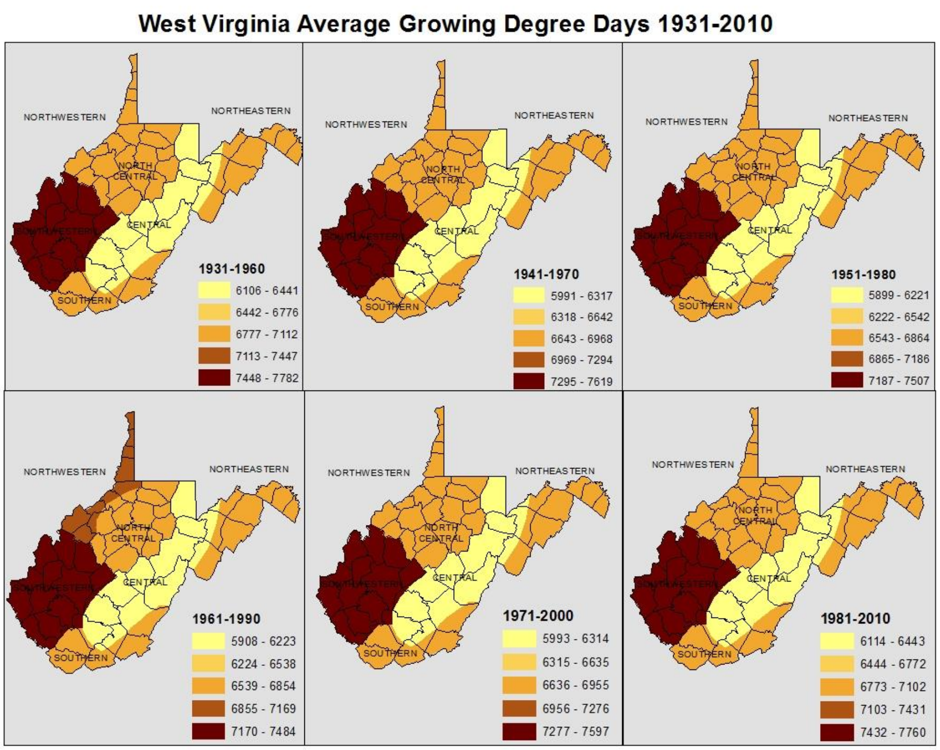

Figure 12 - West Virginia Averaged Growing Degree Days- 1931-2010.

Precipitation. The final precipitation results revealed that every region in West Virginia has adequate precipitation and met the hemp agronomic requirements for precipitation. The West Virginia precipitation levels have a stable increasing trend, which means that the hemp cultivation and industrial applications have a steady environment to operate and grow the economy. This layer was not included in the main spatial output since the climatological analysis of each climate division has assured that the binary output of this layer would be all ones throughout the entire state of West Virginia.

The first NOAA NCDC climate division is the northwestern division. The northwestern climate division comprises the West Virginia northern panhandle. The counties it covers are Hancock, Brooke, Ohio, Marshall, the Northern part of Wetzel county, western half of Tyler county, Pleasants, Wood, Wirt, and the eastern half of Ritchie County. The precipitation levels have shown increased trend in the amounts of precipitation in the division throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* The precipitation amounts are evidenced in both the charts, Figure 13 for the division and Figure 19 for the state and spatially represented in Figure 20 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span.

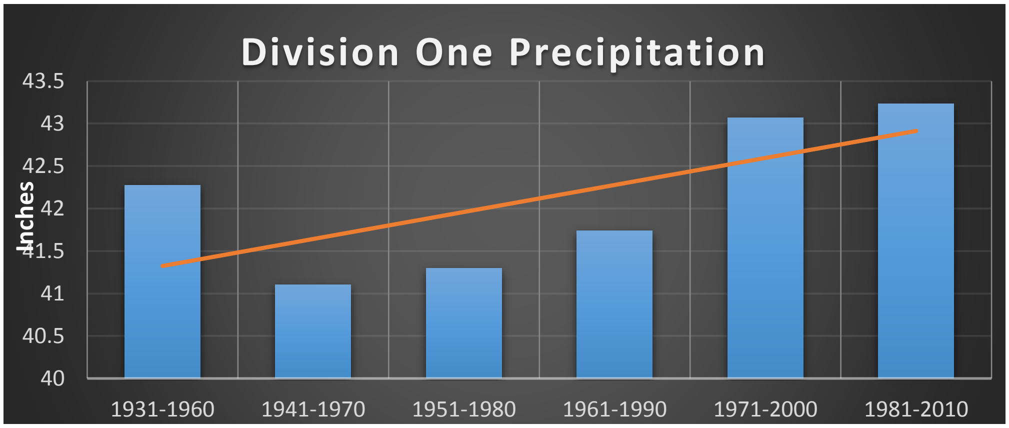

Figure 13 - Precipitation Amounts for Division One- 1931-2010.

The second NOAA NCDC climate division is the north central division. The north central climate division comprises the West Virginia counties located right below the northern panhandle. The counties it covers are Braxton, Upshur, Taylor, Barbour, Harrison, Lewis, Gilmer, Calhoun, Doddridge, Marion, Monongalia, the eastern halves of Ritchie, Tyler, and the southern half of Wetzel. The precipitation levels have shown increased trend in the amounts of precipitation in the division throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* The precipitation amounts are evidenced in both the charts Figure 14 for the division and Figure 19 for the state and spatially represented in Figure 20 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span.

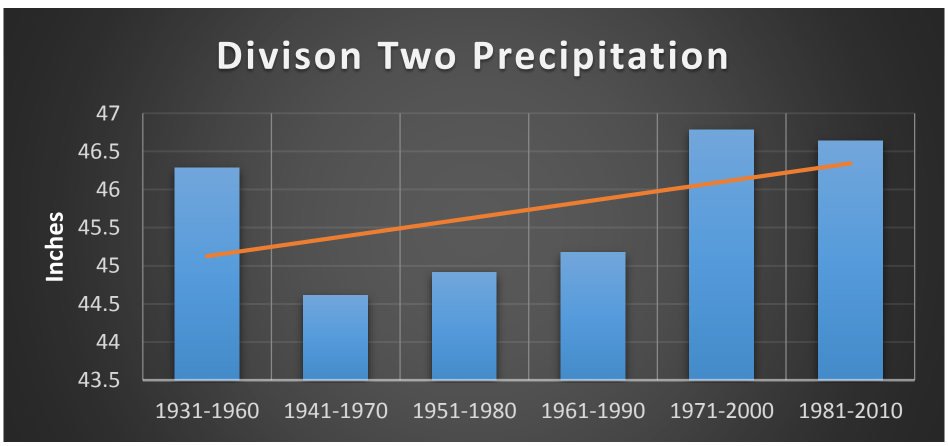

Figure 14 - Precipitation Amounts for Division Two- 1931-2010.

The third NOAA NCDC climate division is the southwestern division. The southwestern climate division comprises the West Virginia counties located in the state's far western corner and bordered on the west by the Ohio River. The counties it covers are Mingo, Wayne, Cabell, Lincoln, Logan, Boone, Kanawha, Clay, Roane, Jackson, Mason, and Putnam counties. The precipitation levels have shown increased trends in the amounts of precipitation in the division throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* The precipitation amounts are evidenced in both the charts Figure 15 for the division and Figure 19 for the state and spatially represented in Figure 20 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span.

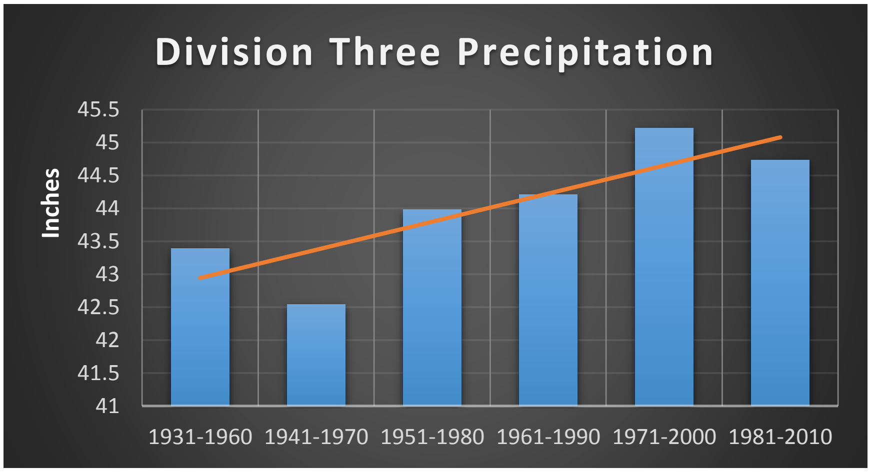

Figure 15 - Precipitation Amounts for Division Three- 1931-2010.

The fourth NOAA NCDC climate division is the central division. The central climate division comprises the West Virginia counties located in the state's far eastern corner and has the majority of the state's Appalachian Mountains. The counties it covers are Preston, Tucker, Randolph, Webster, Nicholas, Fayette, Pocahontas, the northern tip of Mercer County, and the western halves of Summers, Greenbrier, and Pendleton Counties. The precipitation levels have shown an increased trend in the amounts of precipitation in the division throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* The precipitation amounts are evidenced in both the charts Figure 16 for the division and Figure 19 for the state and spatially represented in Figure 20 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span.

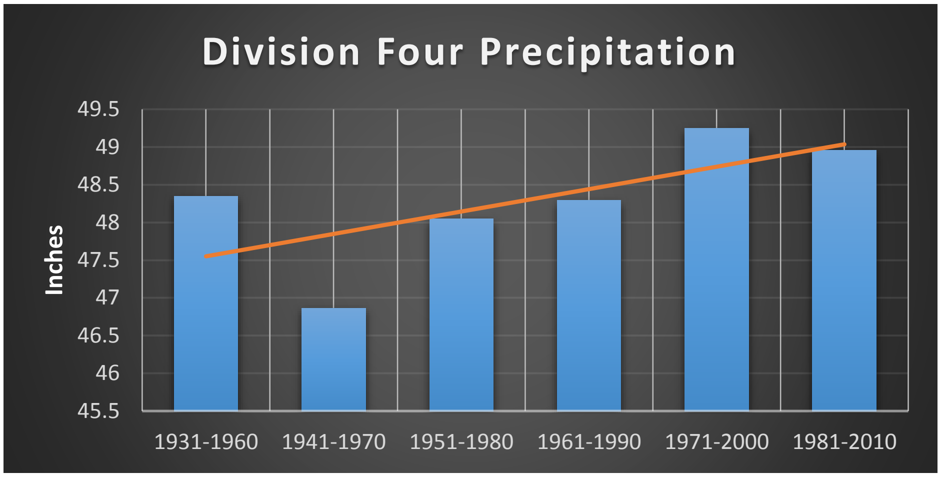

Figure 16 - Precipitation Amounts for Division Four- 1931-2010.

The fifth NOAA NCDC climate division is the southern division. The southern climate division comprises the West Virginia counties located in the far southern portion of the state. The counties it covers are Mc Dowell, Wyoming, Monroe, the southern half of Mercer County, and the eastern half of Summers county. The precipitation levels have shown increased trend in the amounts of precipitation in the division throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* The precipitation amounts are evidenced in both the charts, Figure 17 for the division and Figure 19 for the state and spatially represented in Figure 20 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span.

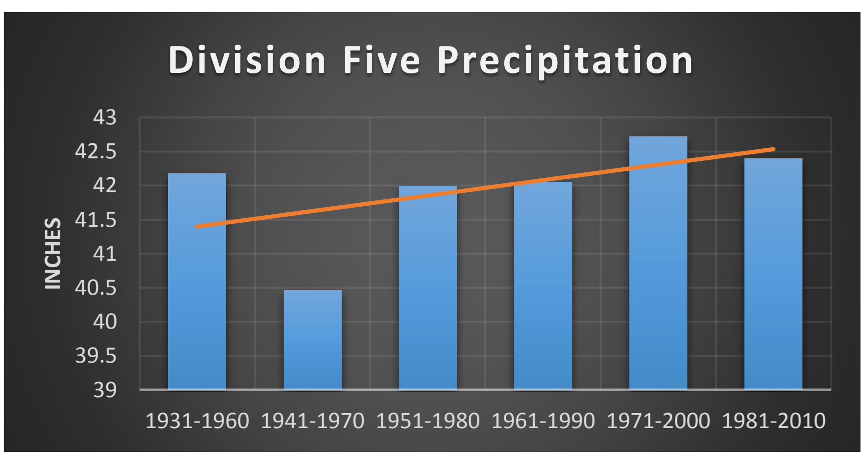

Figure 17 - Precipitation Amounts for Division Five- 1931-2010.

The sixth NOAA NCDC climate division is the northeastern division. The northeastern climate division comprises the West Virginia counties located in the state's far eastern corner and has the rest of the state's Appalachian Mountains and is bordered by the Potomac River. The counties it covers are Jefferson, Berkeley, Morgan, Hampshire, Hardy, Mineral and the eastern halves of Grant and Pendleton Counties. The precipitation levels have shown increased trend in the amounts of precipitation in the division throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* The precipitation amounts are evidenced in both the charts, Figure 18 for the division and Figure 19 for the state and spatially represented in Figure 20 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span. The overall lower precipitation levels would not be the most optimal area to establish hemp fiber cultivation as an industry.

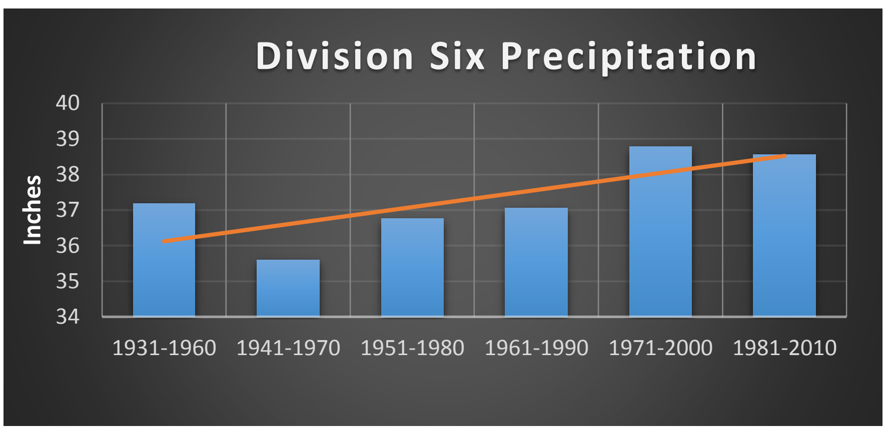

Figure 18 - Precipitation Amounts for Division Six- 1931-2010.

The overall West Virginia Precipitation Normal is shown in the last graph for the eighty-year period 1931-2010 and separated in thirty-year increments: 1931-1960, 1941-1970, 1951-1980, 1961-1990, 1971-2000, and 1981-2010. Figure 19 was calculated by finding the percentage of land area in each climate division. The total amount of land area was divided into each climate classification division in order to find the amount of land contained in each climate division. This percentage was then multiplied into a climate division averaged total for the years

1931-1960, 1941-1970, 1951-1980, 1961-1990, 1971-2000, and 1981-2010 respectively. The precipitation levels have shown increased trend in the amounts of precipitation throughout the entire state throughout the entire eighty-year span showing that it is capable of supporting hemp fiber cultivation and show there is sufficient precipitation to cultivate *Cannabis Sativa L.* This is evidenced in both the chart, Figure 19, and spatially represented in Figure 21 with the exact amount given in Table 4 for each thirty-year period over the eighty-year span.

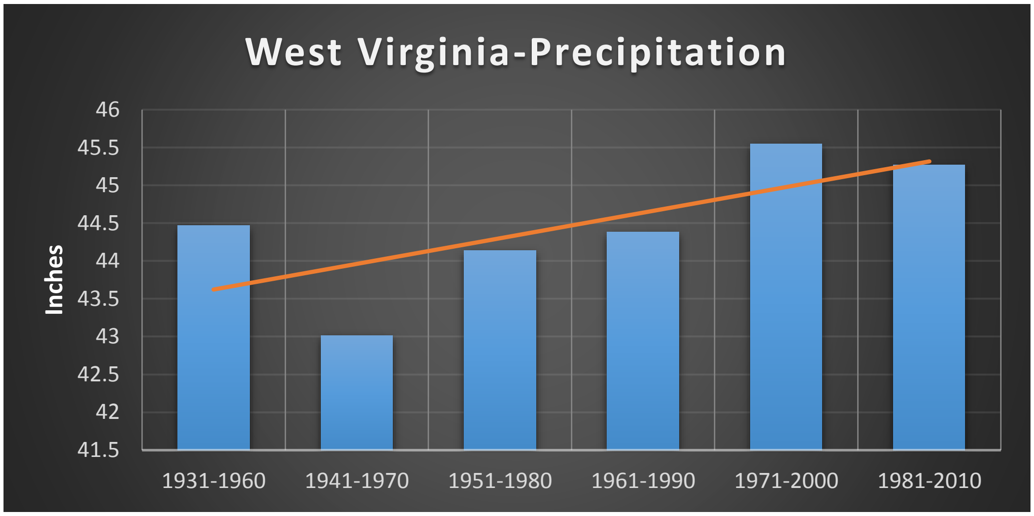

Figure 19 - Precipitation Amounts for West Virginia 1931-2010.

Table 4 - Averaged Precipitation Amounts for West Virginia for 1931-2010.

West Virginia Division Averaged Precipitation Amounts and Total In Inches						
Division	**1931-1960**	**1941-1970**	**1951-1980**	**1961-1990**	**1971-2000**	**1981-2010**
Northwestern	42.28	41.10	41.30	41.74	43.07	43.23
North Central	46.29	44.61	44.91	45.17	46.79	46.64
Southwestern	43.39	42.54	43.98	44.21	45.22	44.73
Central	48.35	46.87	48.05	48.29	49.25	48.96
Southern	42.18	40.46	41.99	42.06	42.72	42.40
Northeastern	37.18	35.60	36.76	37.07	38.77	38.56
Total	**44.47**	**43.01**	**44.14**	**44.38**	**45.55**	**45.27**

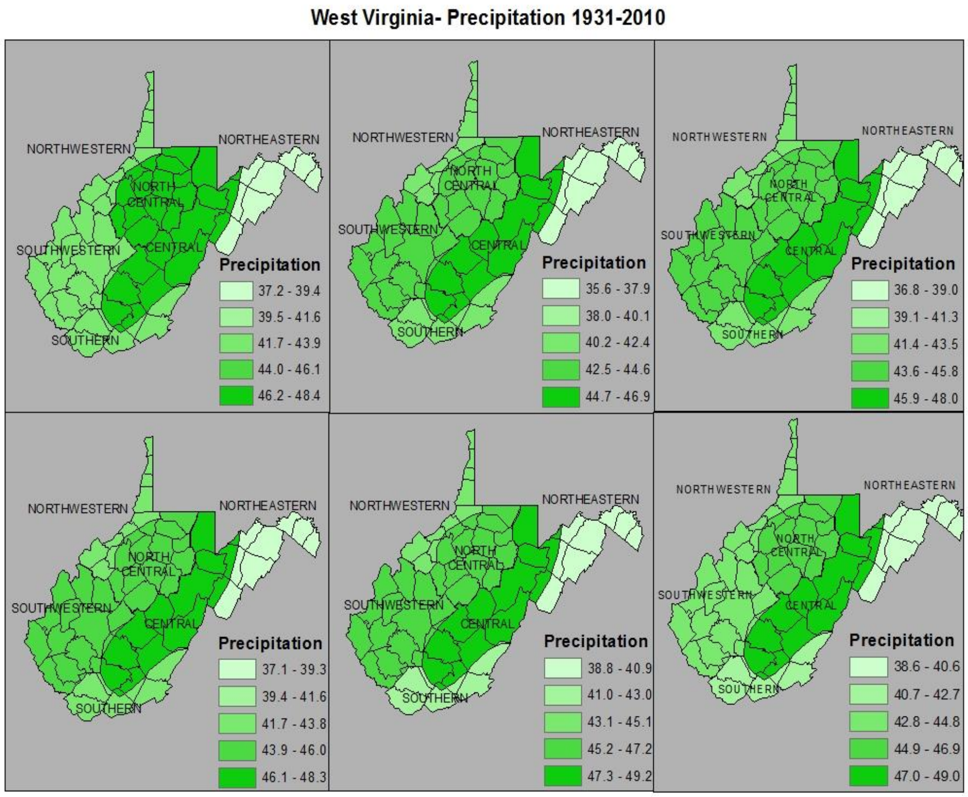

Figure 20 - Precipitation Amounts for West Virginia 1931-2010.

Every one of the climatological factors showed a positive trend revealing that *Cannabis Sativa L* could indeed be successfully cultivated in West Virginia's climate. Considering this fact, these variables were not included in the final agricultural cartographic expression, since each factor would have been the expression of true or 1 in the binary analysis. The next part of the agricultural analysis was the terrain analysis from which soil composition, drainage qualities, altitude, slope and aspect were examined and reclassified into either 0 or 1. The results for altitude in West Virginia revealed that the eastern half of the state containing the Appalachian Mountains were discarded because of these unfavorable conditions for hemp fiber growth. The finished agricultural layer revealed the available hemp cultivation sites as in the raw capacity of the region to cultivate hemp fiber. The total amount of acreage for West Virginia is 3,633,931.74 acres of raw agricultural hemp cultivation potential. The agricultural layer is presented with counties added to provide a broad geographic reference and is represented spatially in Figure 21.

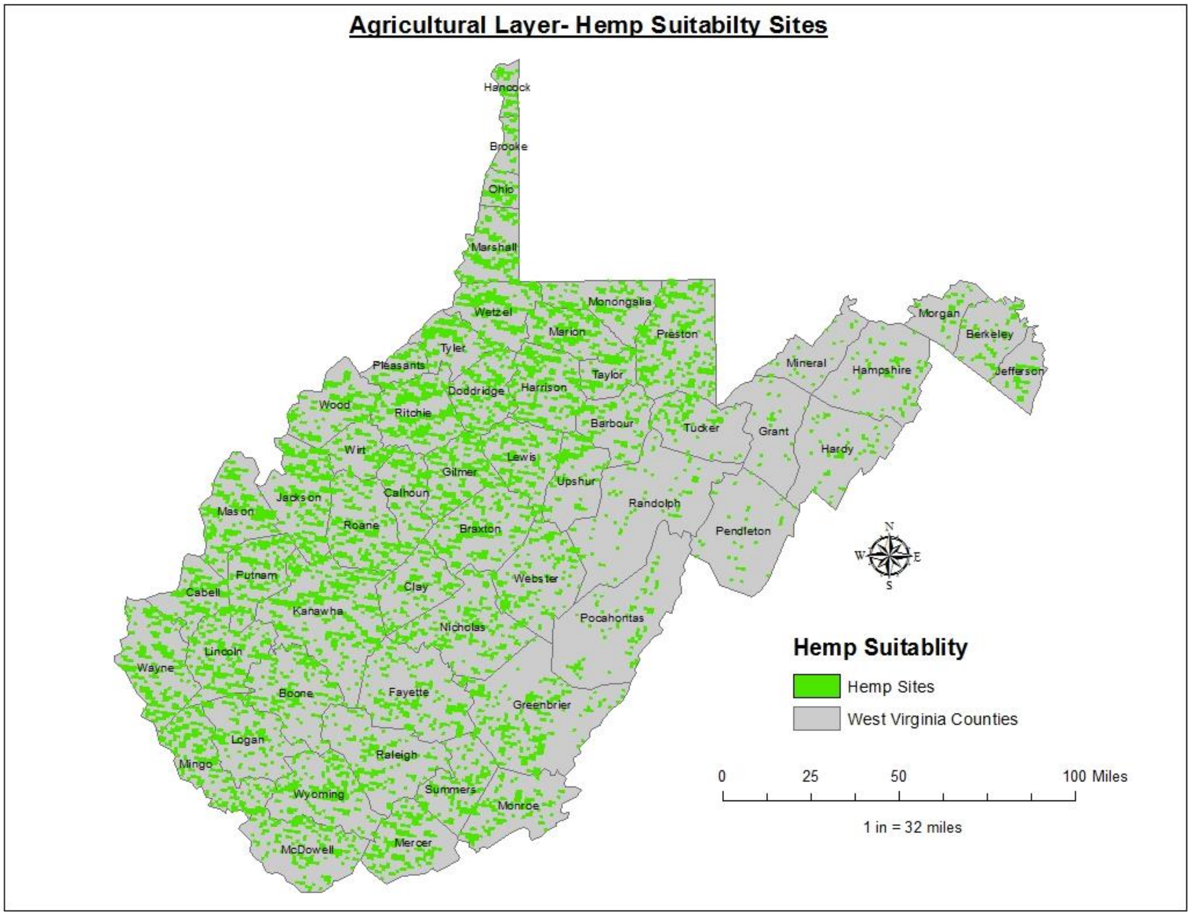

Figure 21 - Agricultural Layer.

Urban Layer. The finished urban layer, spatially represented in Figure 22, revealed the available hemp cultivation sites in relation to urban planning land use classification of the available sites to cultivate hemp fiber, within the current LULC classification. The urban layer showed the power that planning and land use and land cover classification has upon an agricultural suitability analysis. It also revealed the areas of land use land cover conflict associated with anthropogenic classification versus the raw agricultural output. From the 3,633,931.74 acres located in the agricultural layer after raster calculating the area a much smaller amount of hemp suitable sites acreage for West Virginia became 448,125.6093 acres also represented in Figure 25 and Table 5. Hemp suitable acreage was further reduced by stakeholder preferences to 419,449.866 as evidenced in Figure 24 and exact amounts in Table 5.

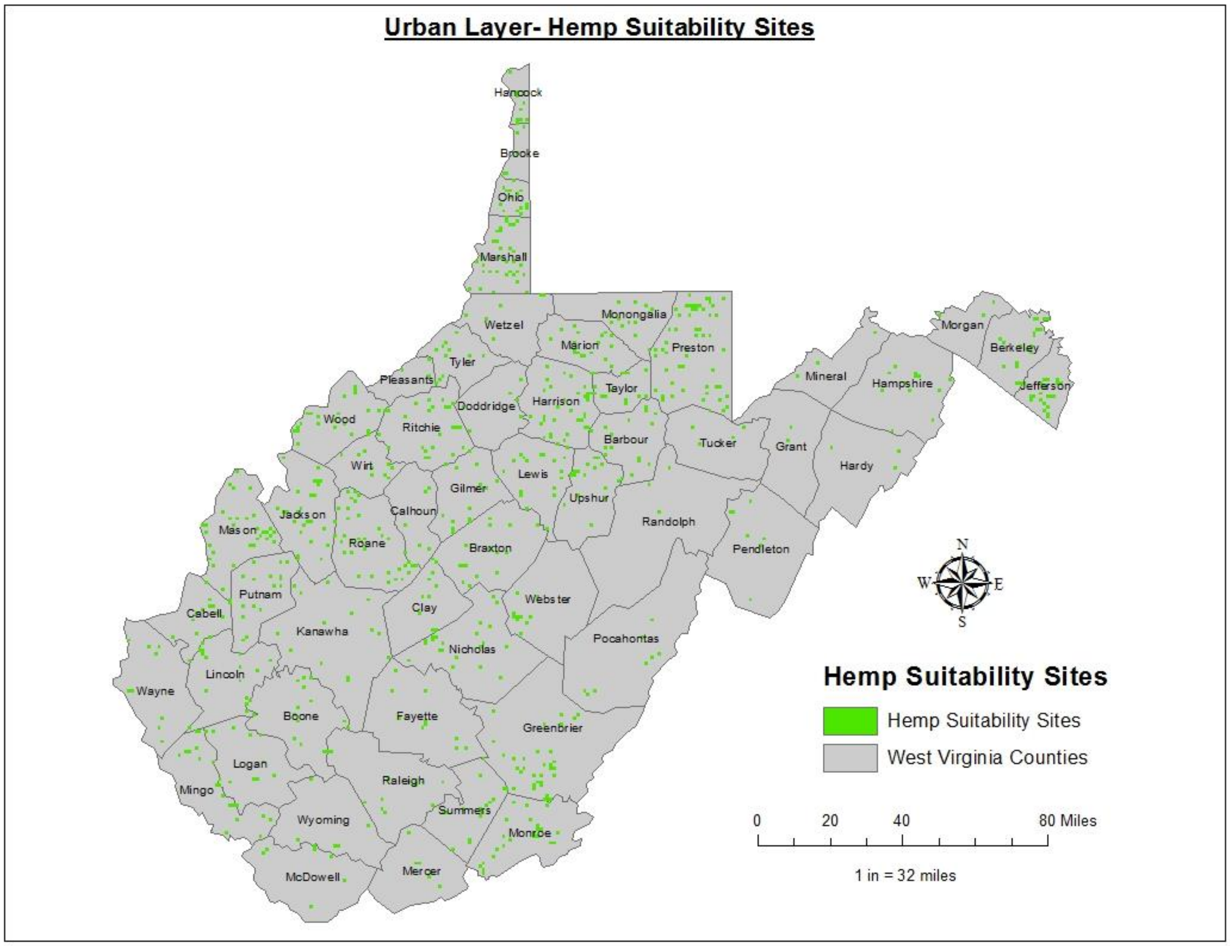

Figure 22 - Urban Layer.

Contamination Layer and Hemp Suitable Sites. The finished contamination layer, which is spatially represented in Figure 23, revealed the location of the available hemp cultivation sites capacity within the state to cultivate hemp fiber which could have the possibility of acid mine drainage contamination. This layer should only be used as a guide for determining which sites could have the potential to have acid mine drainage, not a comprehensive list of verified acid mine drainage contamination sites. Possible contaminated hemp cultivation sites should be thoroughly and scientifically ground proofed and analyzed before any cultivation hemp fiber should begin to prevent the possibility of contaminated hemp fiber being used for human consumption products.

The total area of West Virginia, according to the NCDC, is 24,181 square miles or 15,475,840 acres of the state's total area. The three layers, agricultural, urban and contamination, reveals the conflict between hemp cultivation potential overall and current potential. The agricultural layer revealed that 3,633,931.74 acres of the state of West Virginia has the capacity to cultivate *Cannabis Sativa L.* for fiber processing. The agricultural capacity is 23.48% percent of the state. However the amount of hemp suitable cultivation sites acreage decreases dramatically to 448,125.6093 acres when raster calculated with the reclassified urban layer. This conflict between the agricultural potential and the actual landuse severely reduced the percentage of the state that hemp can be cultivated to 2.89%. The current capacity of the state to cultivate hemp fiber and the vector sculpting from stakeholder preferences calculated a smaller amount of hemp suitable sites acreage leaving the total acreage at 419,449.866 as evidenced in Figure 24 and exact amounts in Table 5. However out of the 419,449.866 acres as hemp suitable sites, the contamination layer identified the location of possible compromised hemp suitable sites having a total of 199,127.8199 acres. This result of total 220,322.0461 acres of suitable hemp cultivation sites without the possibility of acid mine drainage contamination as referenced in Figure 24 and with exact amounts in Table 5. Dividing both non-contaminated and possibly contaminated hemp cultivation sites by the eleven regional planning commissions as evidenced in Figures 25-35 and in Table 6 list possible incorporated areas that may use hemp cultivation for sustainable development. Some potential contaminated sites may not be contaminated and each potential site requires extensive ground proofing and scientific soil analysis before cultivation may begin.

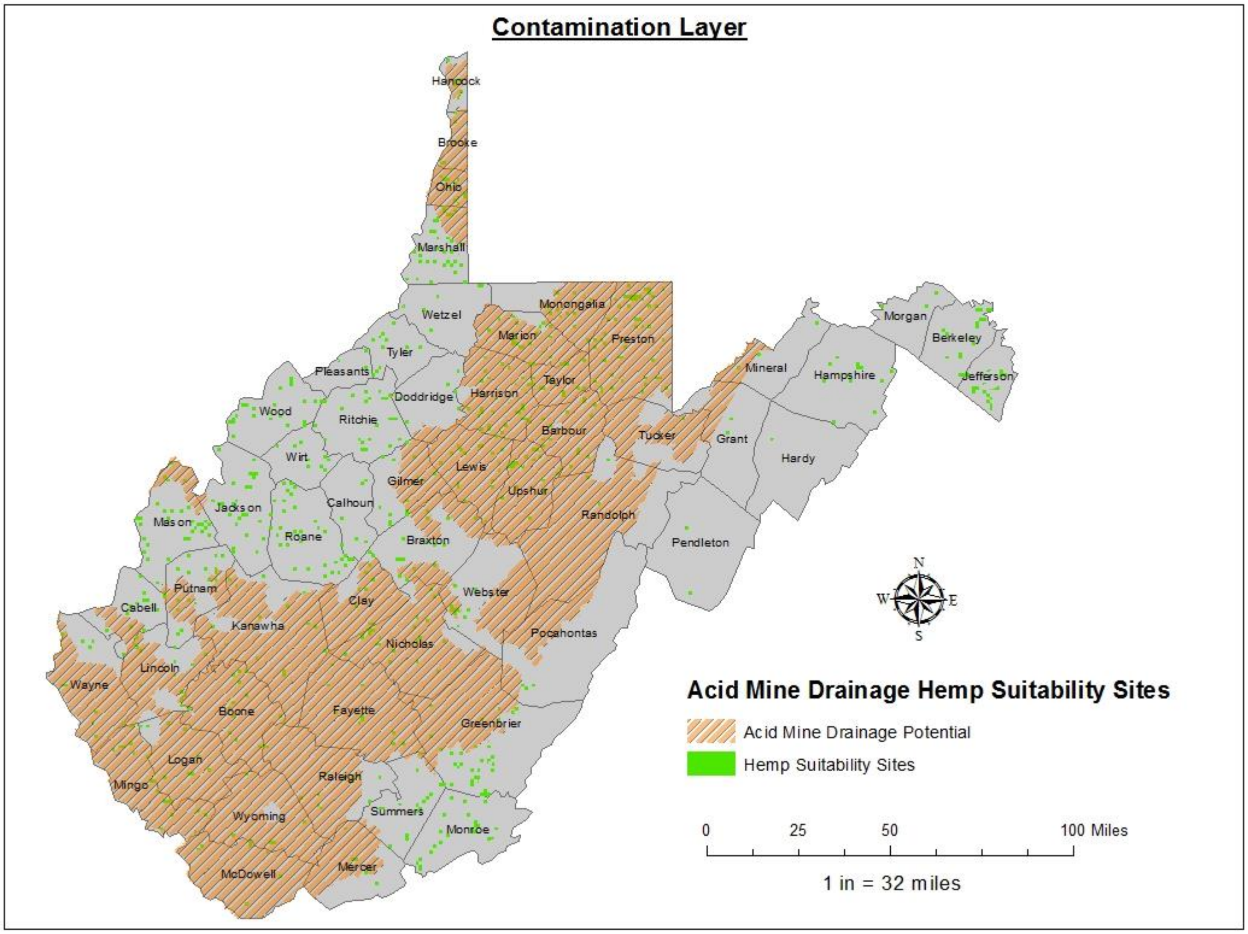

Figure 23 - Contamination Layer.

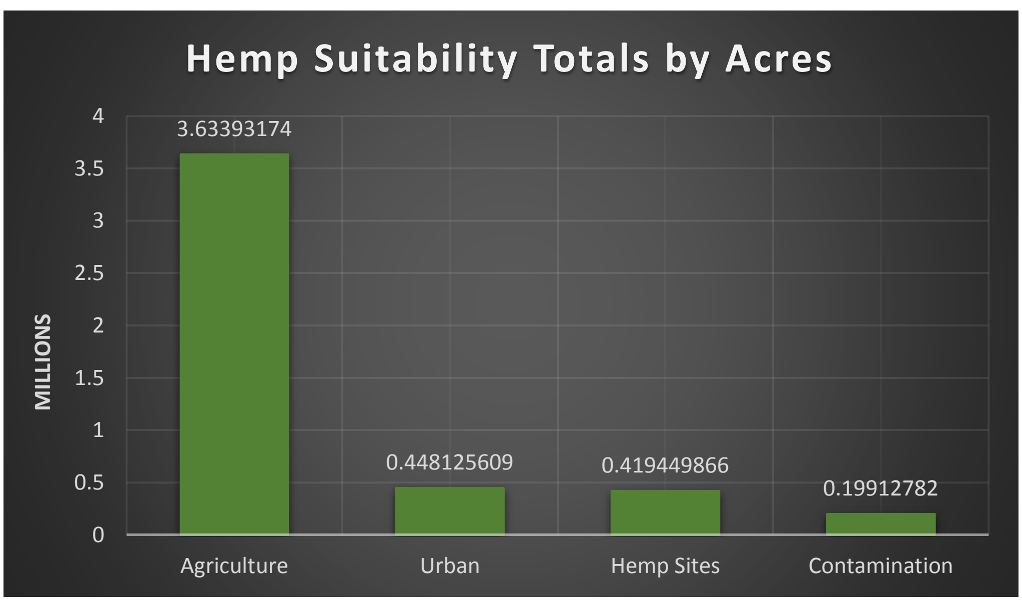

Figure 24 - Hemp Suitability Sites by Layer in Acres.

Table 5 - Hemp Suitability Site by Layer in Total Acreage and Percentages.

Units	Agriculture	Urban	Hemp Sites	Contamination
Acres	3,633,931.74	448,125.6093	419,449.866	199,127.8199
Percent	23.48%	2.89%	2.71%	1.28%

Planning and Hemp. The units for the final analysis for the hemp suitability sites results for West Virginia are divided into the eleven planning and development councils which help govern and guide the development of West Virginia LULC planning efforts for sustainable development. (WVGISTC, 1971). The eleven West Virginia planning regions covers the entire 55 counties listed in Table 6.

Table 6 - Planning Regions and West Virginia Counties.

Planning Region	Counties
Region 1–Planning and Development Council	McDowell, Mercer, Monroe, Raleigh, Summers, Wyoming
Region 2–Planning and Development Council	Cabell, Lincoln, Logan, Mason, Mingo, Wayne
Region 3 Regional Intergovernmental Council	Boone, Clay, Kanawha, Putnam
Region 4–Planning and Development Council	Fayette, Greenbrier, Nicholas, Pocahontas, Webster
Region 5–Mid-Ohio Valley Regional Council	Calhoun, Jackson, Pleasants, Ritchie, Roane, Tyler, Wirt, Wood
Region 6–Planning and Development Council	Doddridge, Harrison, Marion, Monongalia, Preston, Taylor
Region 7–Planning and Development Council	Barbour, Braxton, Gilmer, Lewis, Randolph, Tucker, Upshur
Region 8–Planning and Development Council	Grant, Hampshire, Hardy, Mineral, Pendleton
Region 9–Eastern Panhandle Regional Planning and Development Council	Berkeley, Jefferson, Morgan
Region 10–Bel-O-Mar Regional Council and Interstate Planning Commission	Marshall, Ohio, Wetzel
Region 11–Brooke-Hancock Regional Planning and Development Council	Brooke, Hancock

Planners, stakeholders, and the general public should consider how hemp cultivation may be currently utilized in their respective area. Reintroducing the incorporated areas (WVGISTC, 1999) was added to provide a spatial reference for each hemp suitable site and which cities and/or towns may be visually identified for their sustainable development potential. The results are listed in Table 7 and geospatially represented in Figures 25-35 provided for reference.

Table 7 - Incorporated Areas and Possible Hemp Cultivation Sites.

Figure	Planning Region	County	Non-Contaminated Hemp Incorporated Areas	Possible Acid Mine Drainage Contaminated Hemp Incorporated Areas
25	**1**	Mercer	Oakvale	Athens, Princeton
		Monroe	Union, Peterstown, Alderson	N/A
		Raleigh	N/A	Beckley, Mabscott, Sophia
		Summers	Hinton	N/A
		Wyoming	N/A	Mullens
		McDowell	N/A	Welch, Davy
26	**2**	Mingo	N/A	Gilbert
		Logan	N/A	Man, Chapmanville
		Lincoln	N/A	Hamlin
		Wayne	Wayne	Fort Gay
		Cabell	Barboursville, Milton	N/A
		Mason	Henderson	Hartford City
27	**3**	Putnam	Buffalo	Hurricane
		Kanawha	N/A	Marmet, St. Albans, Charleston
		Fayette	N/A	Thurmond
28	**4**	Greenbrier	Lewisburg, Ronceverte, Alderson	Falling Spring, Quinwood
		Nicholas	N/A	Summersville
		Pocahontas	Hillsboro	N/A
		Clay	N/A	Clay
		Webster	Cowen, Camden-on-Gauley	N/A
		Calhoun	Grantsville	N/A
29	**5**	Roane	Reedy	N/A
		Wirt	Elizabeth	N/A
		Jackson	Ripley	N/A
		Wood	Parkersburg	N/A
		Pleasants	St. Marys	N/A
		Ritchie	Cairo, Ellenboro, Pullman, Auburn, Pennsboro	N/A
30	**6**	Harrison	Salem	Lost Creek, West Milford, Bridgeport, Clarksburg,

				Shinniston, Stonewood, Annmore
		Marion	N/A	White Hall, Pleasant Valley, Monongah, Fairmont, Rivesville, Grant Town, Fairview, Mannington
		Monongalia	N/A	Granville, Star City, Westover, Morgantown
		Preston	N/A	Kingwood, Brandonville, Bruceton Mills, Reedsville, Masontown
		Barbour	N\A	Belington
31	**7**	Braxton	Sutton	N\A
		Lewis	N\A	Weston, Jane Lew
		Randolph	N\A	Beverly
		Upshur	N\A	Buckhannon
32	**8**	Hampshire	Capon Bridge	N/A
		Hardy	Moorefield	N\A
		Mineral	N\A	Elk Garden
		Berkeley	Martinsburg	N\A
33	**9**	Jefferson	Ranson, Charles Town, Harpers Ferry, Bolivar	N\A
		Morgan	N\A	N\A
		Wetzel	New Martinsville	N\A
34	**10**	Marshall	Moundsville, Cameron	N\A
		Ohio	N/A	Bethlehem, Triadelphia, Wheeling, Clearview, West Liberty, Valley Grove
		Brooke	N/A	Windsor Heights, Beech Bottom, Follansbee, Wellsburg, Weirton
35	**11**	Hancock	Weirton	New Cumberland

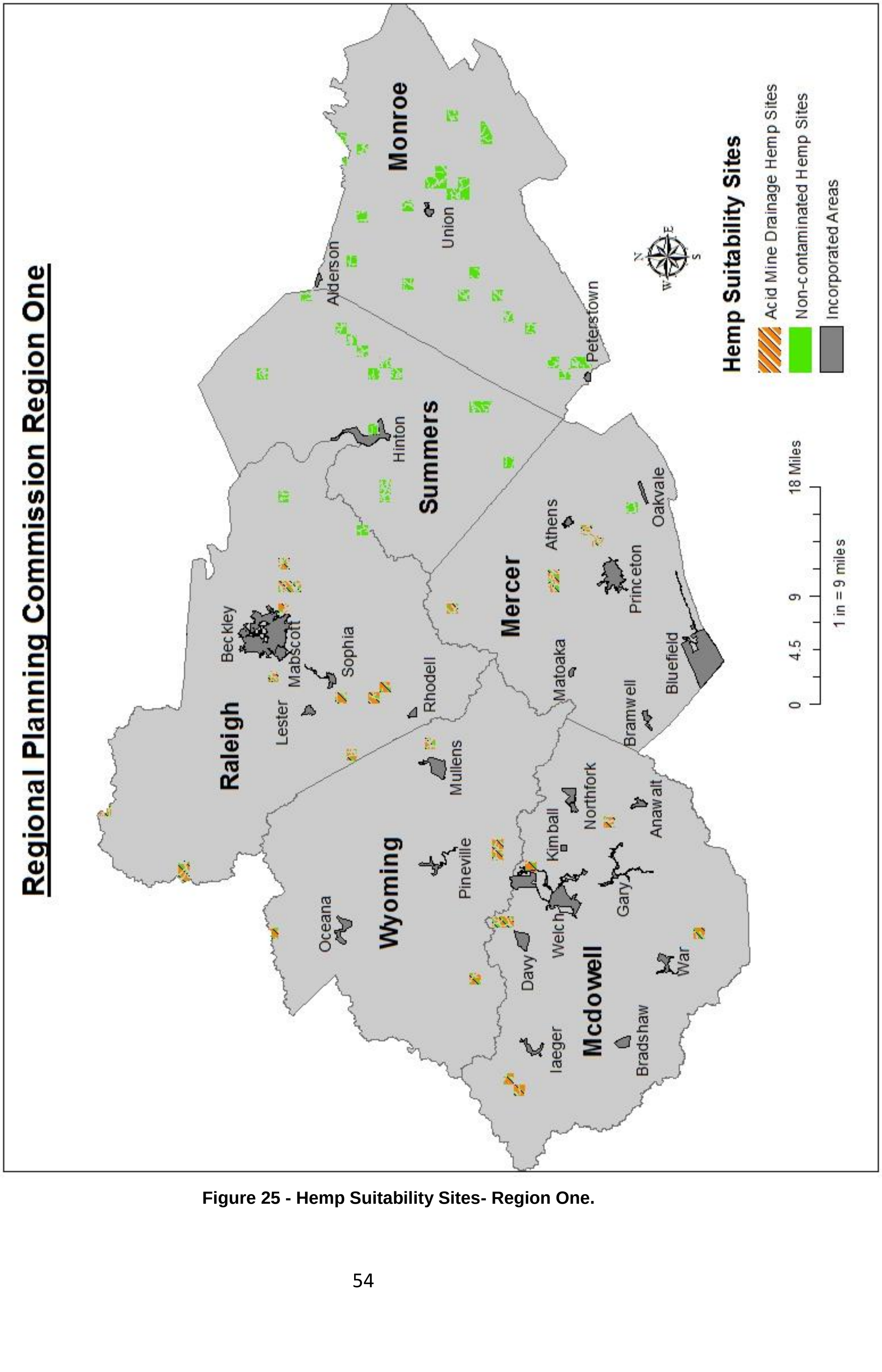

Figure 25 - Hemp Suitability Sites- Region One.

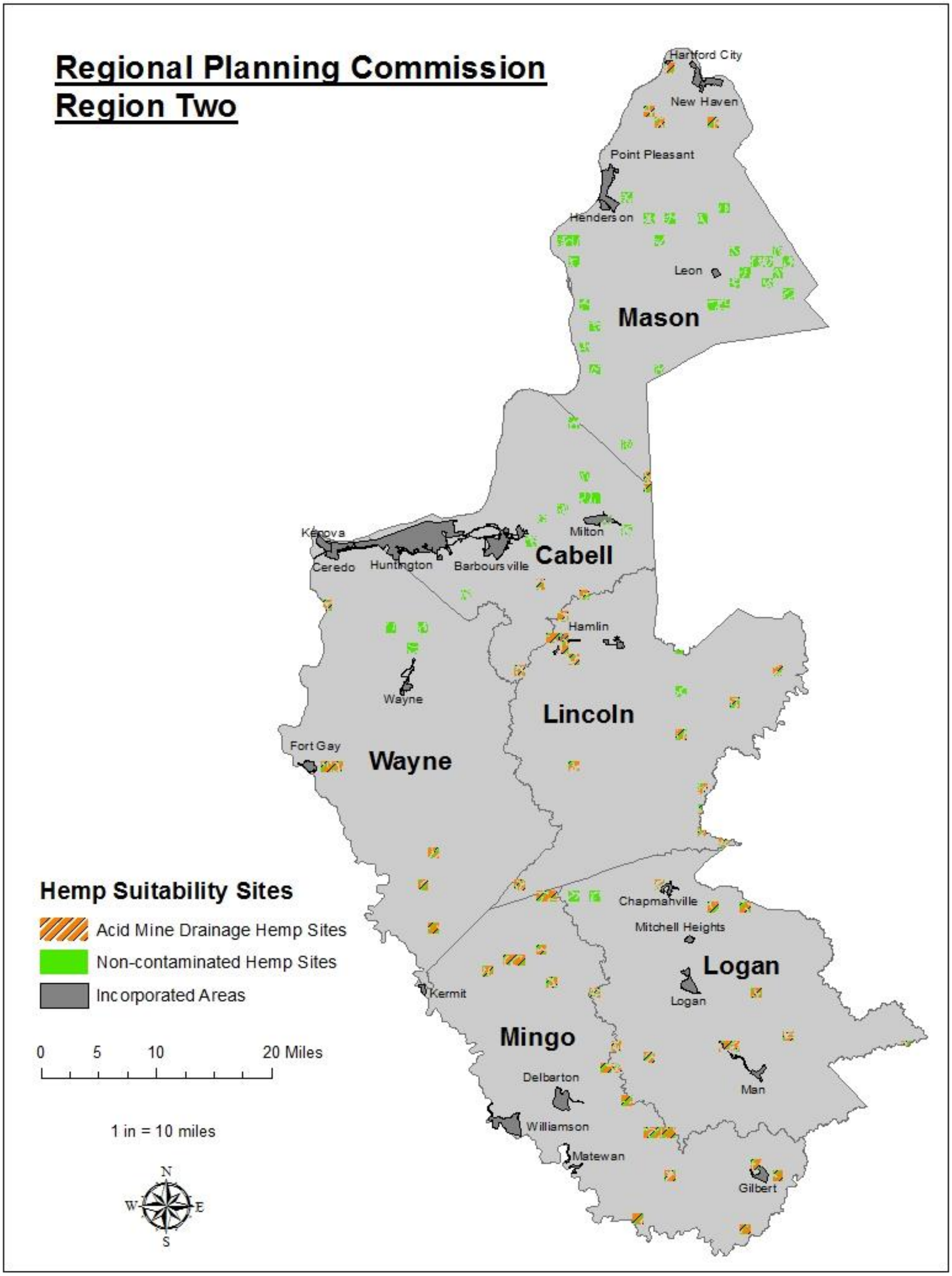

Figure 26 - Hemp Suitability Sites- Region Two.

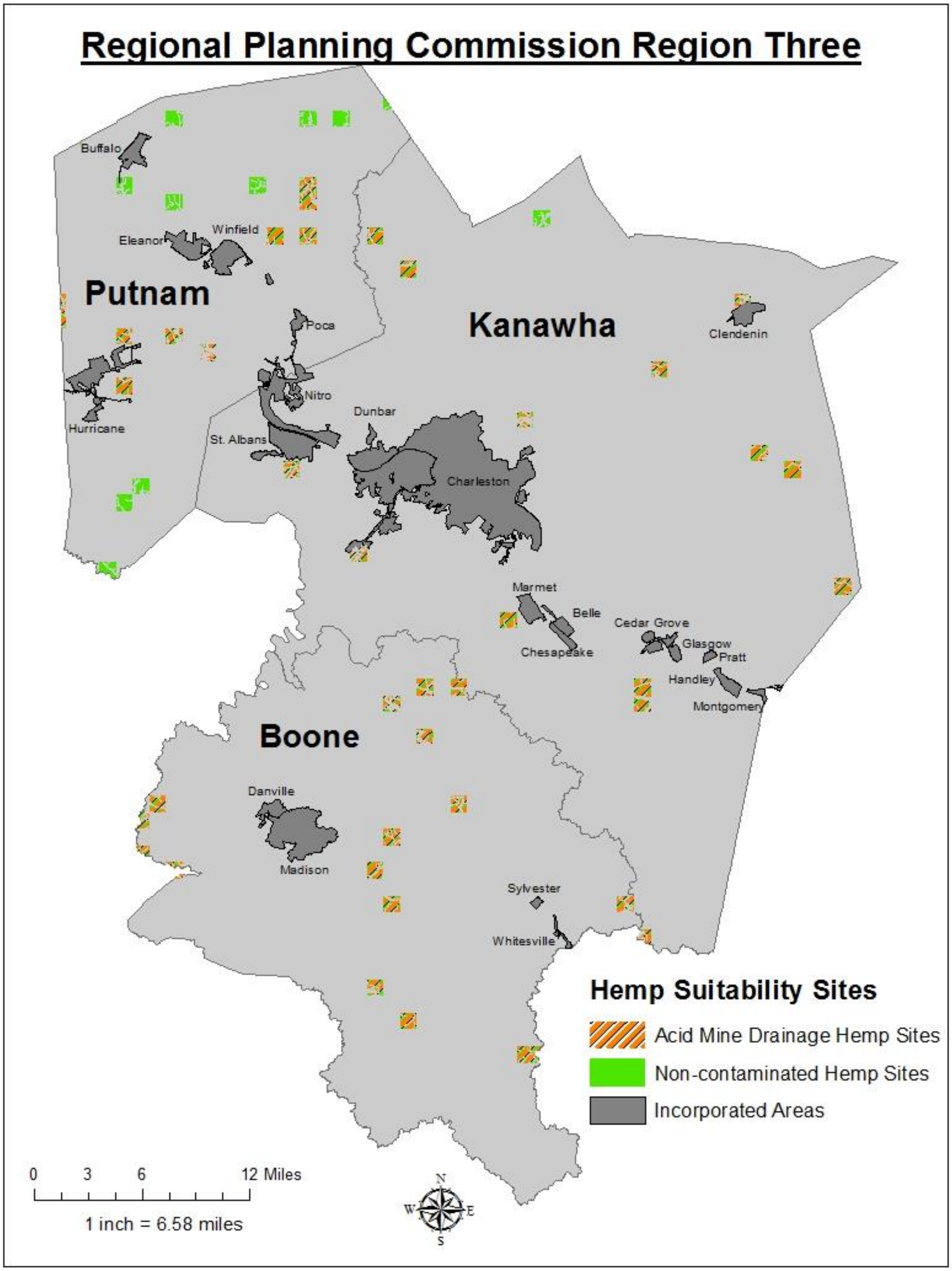

Figure 27 - Hemp Suitability Sites- Region Three.

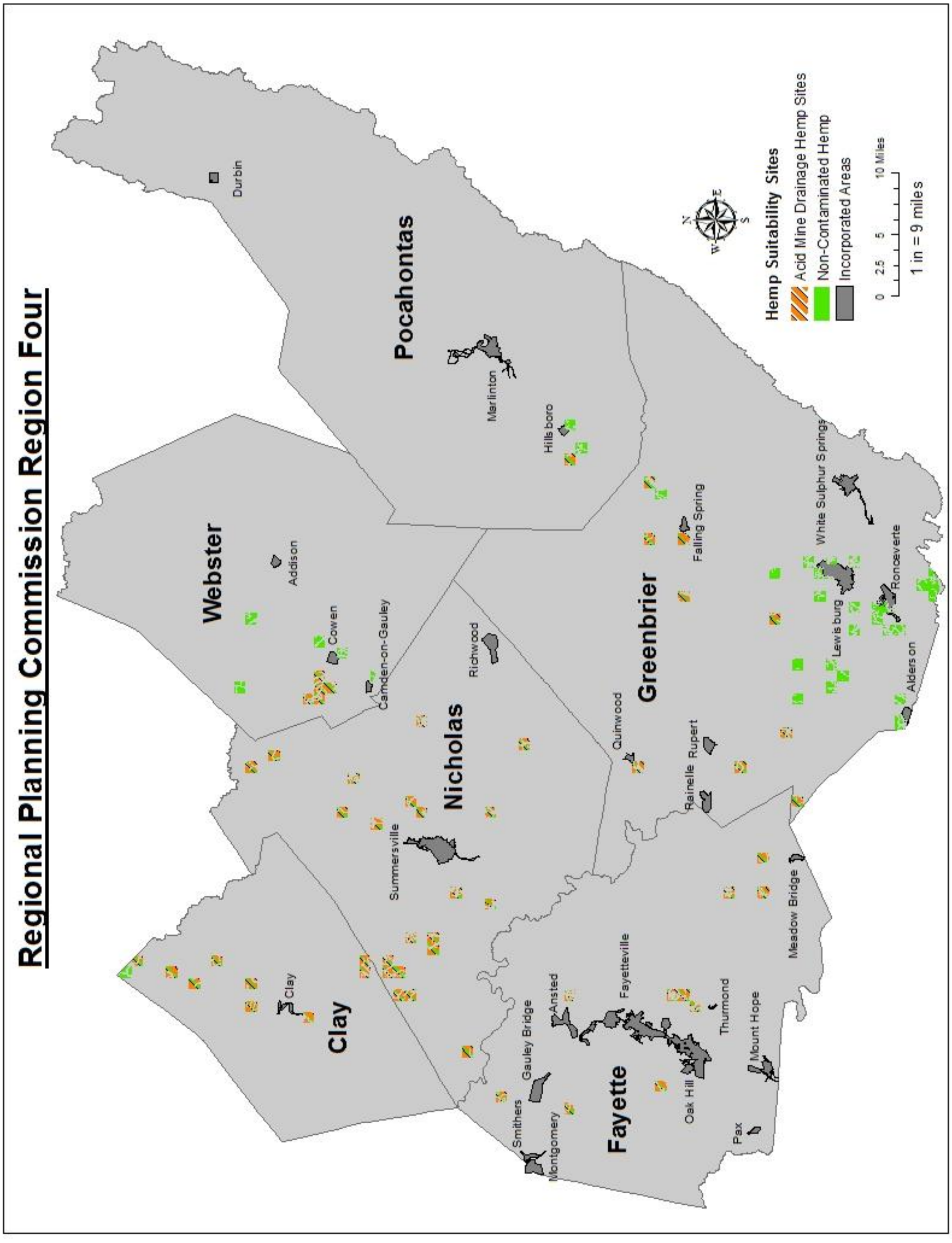

Figure 28 - Hemp Suitability Sites- Region Four.

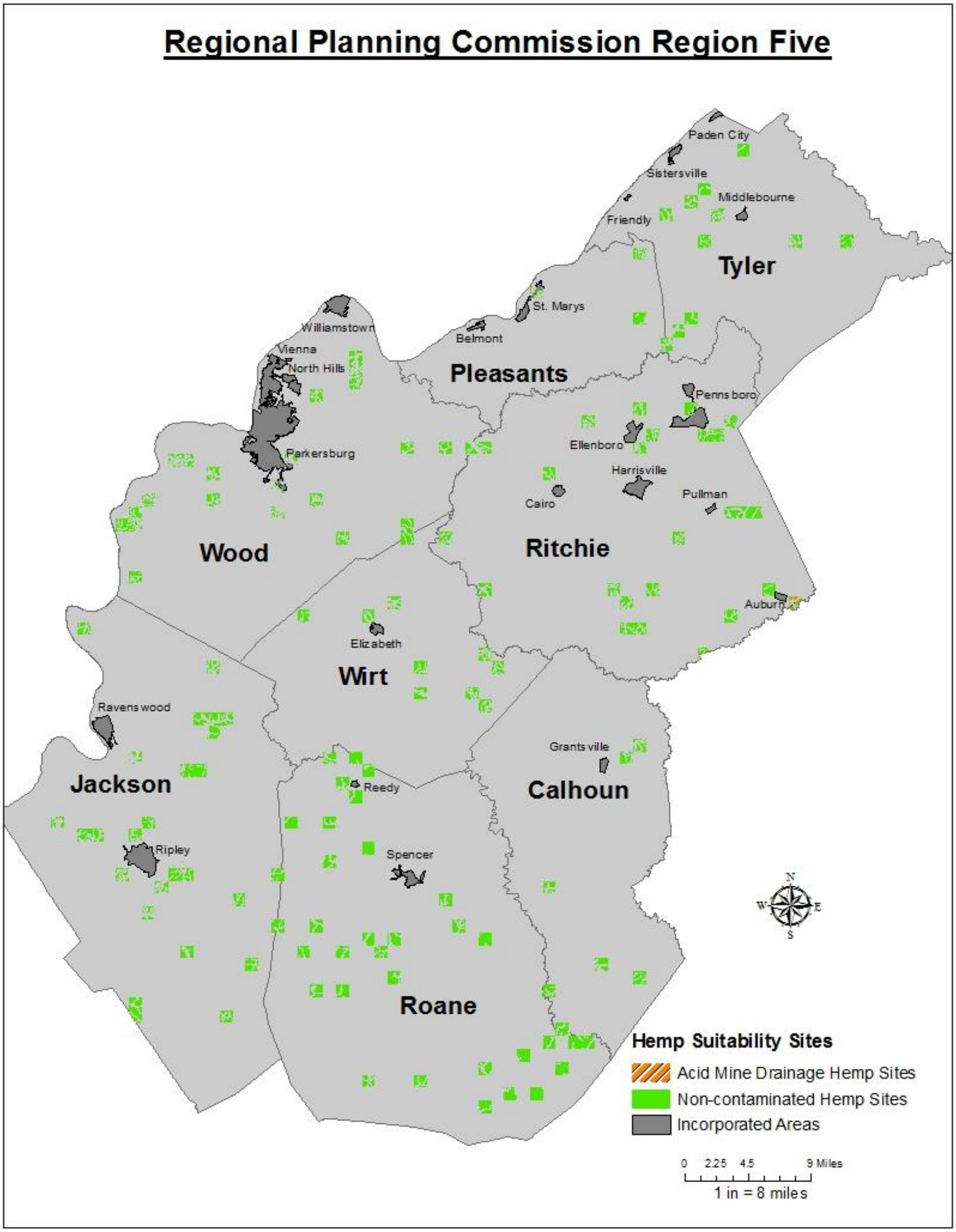

Figure 29 - Hemp Suitability Sites- Region Five.

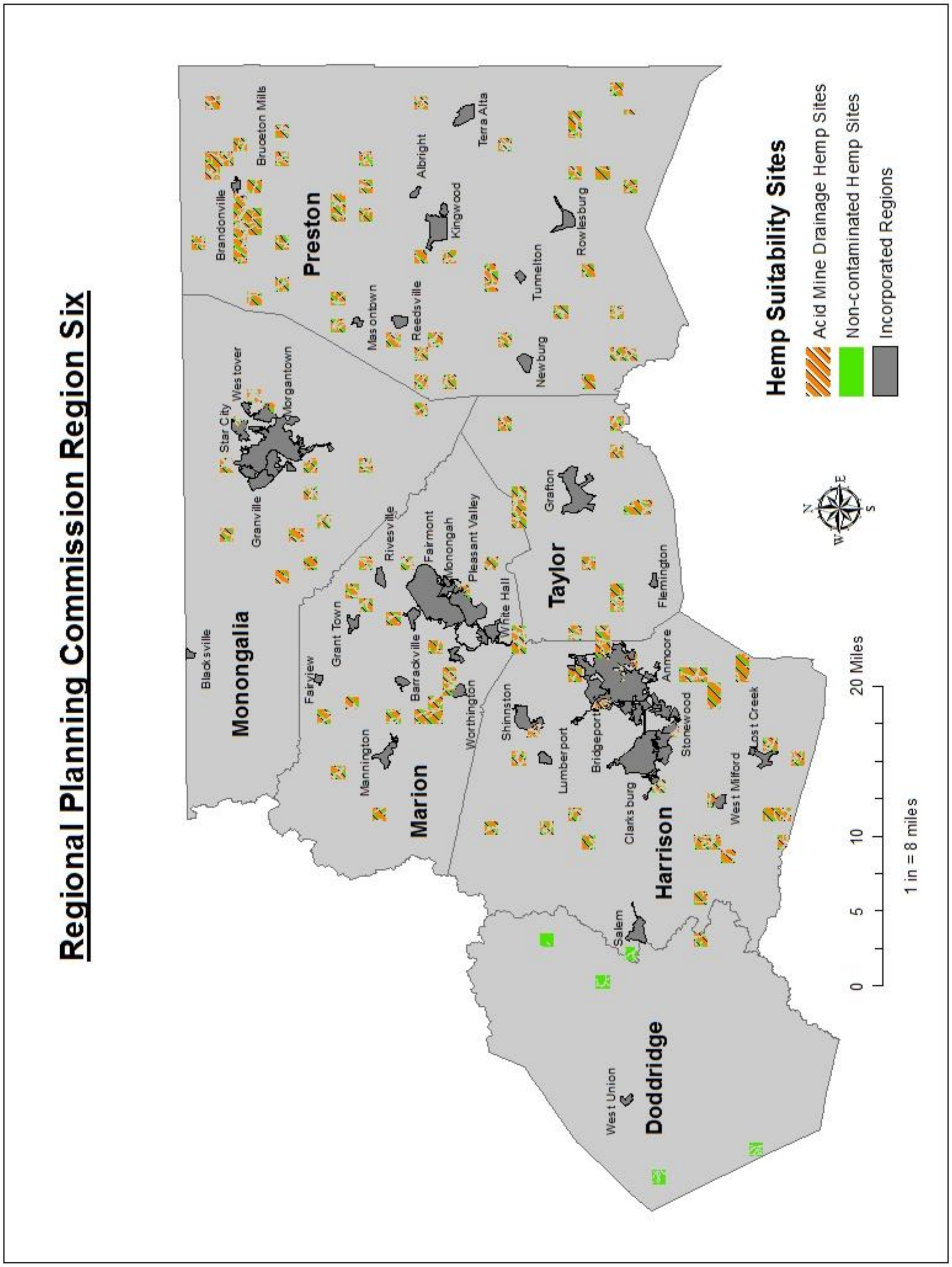

Figure 30 - Hemp Suitability Sites- Region Six.

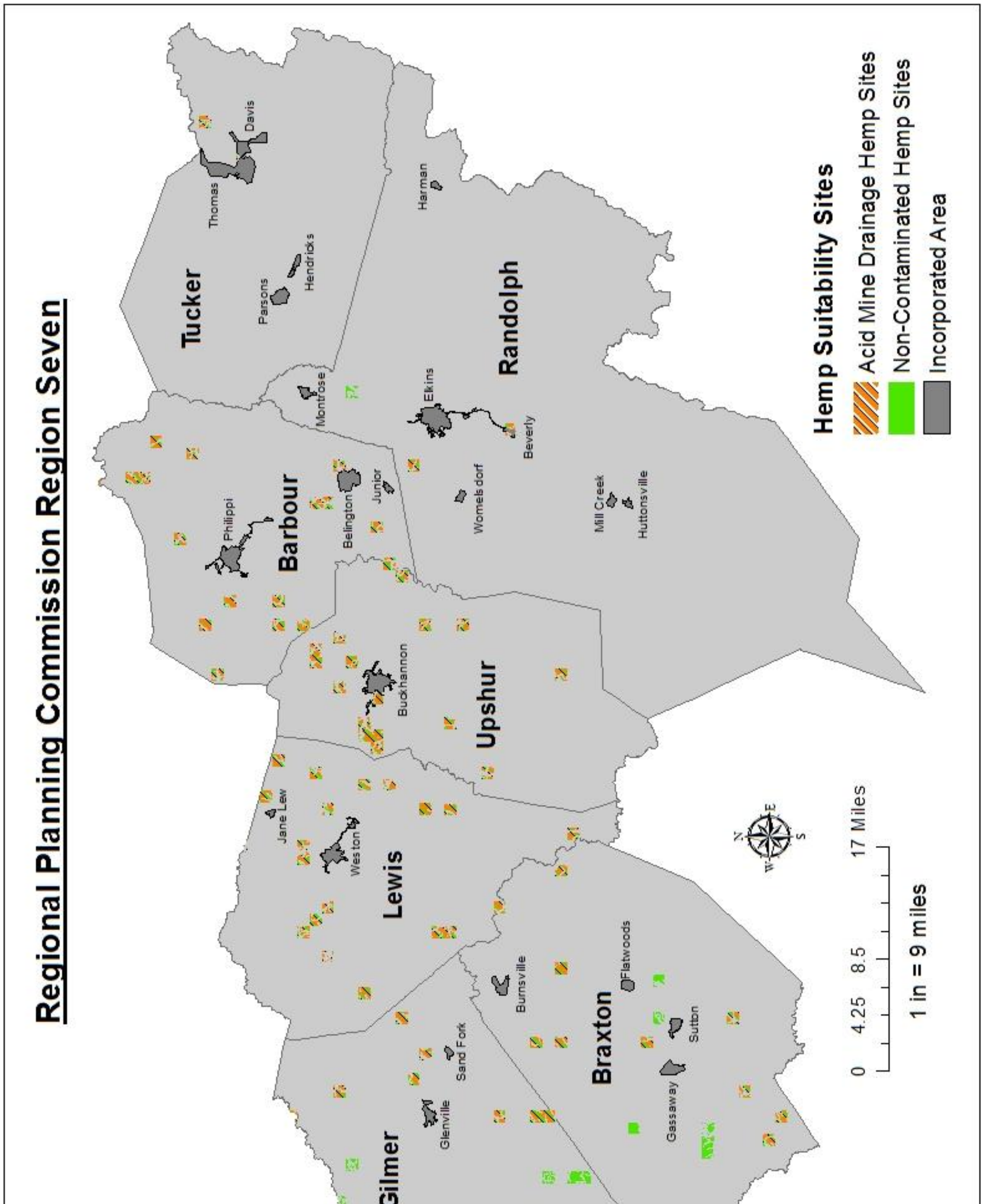

Figure 31 - Hemp Suitability Sites- Region Seven.

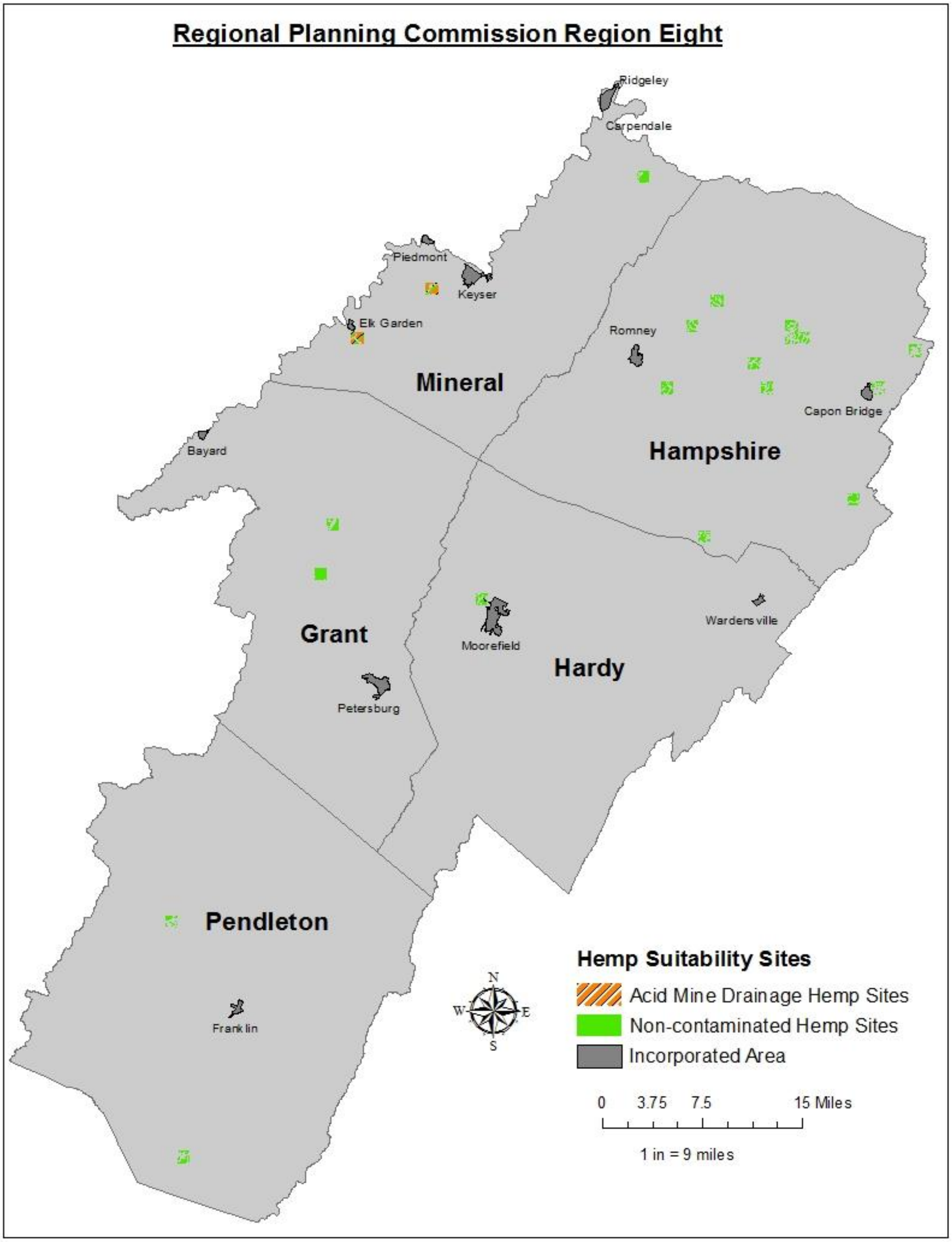

Figure 32 - Hemp Suitability Sites- Region Eight.

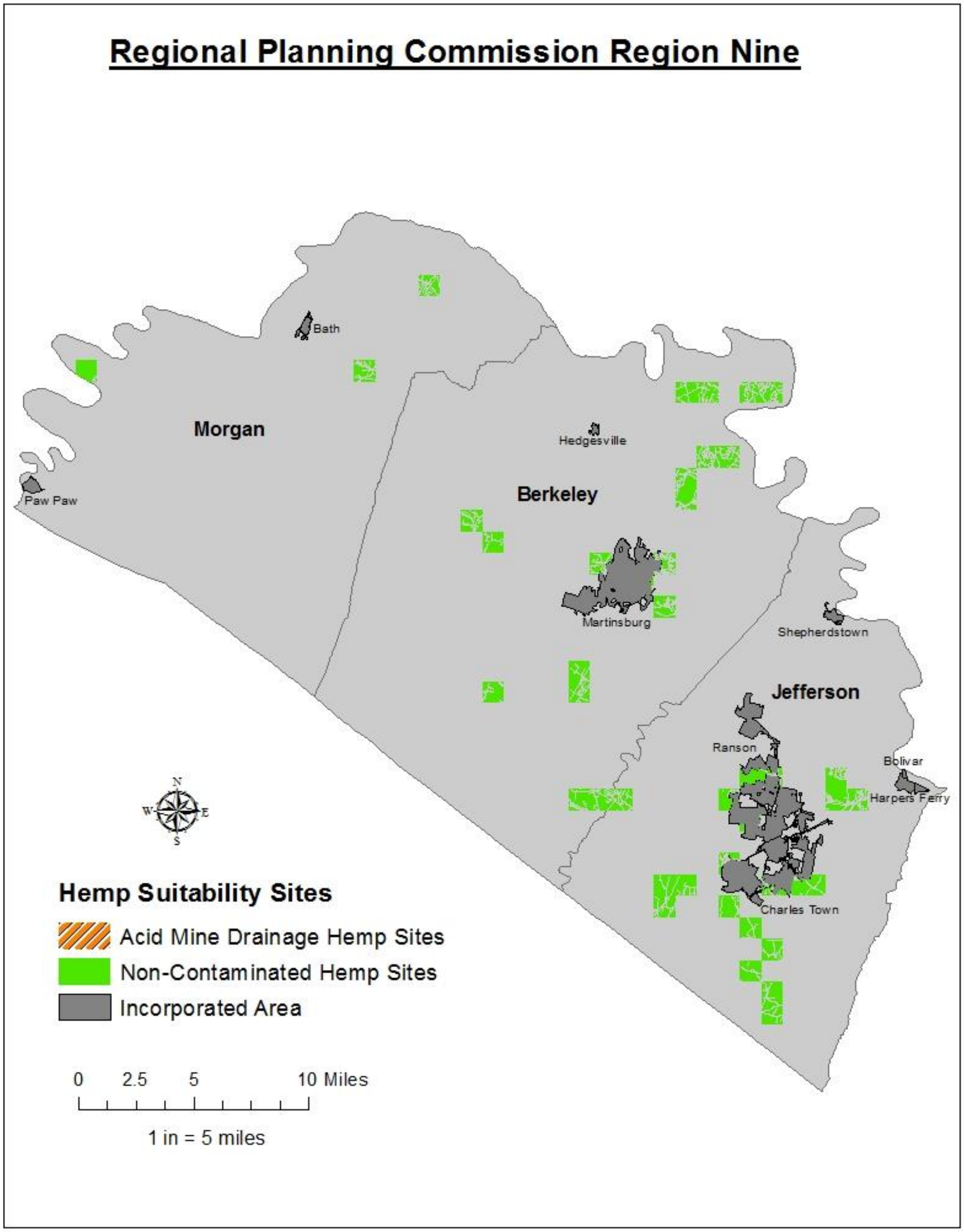

Figure 33 - Hemp Suitability Sites- Region Nine.

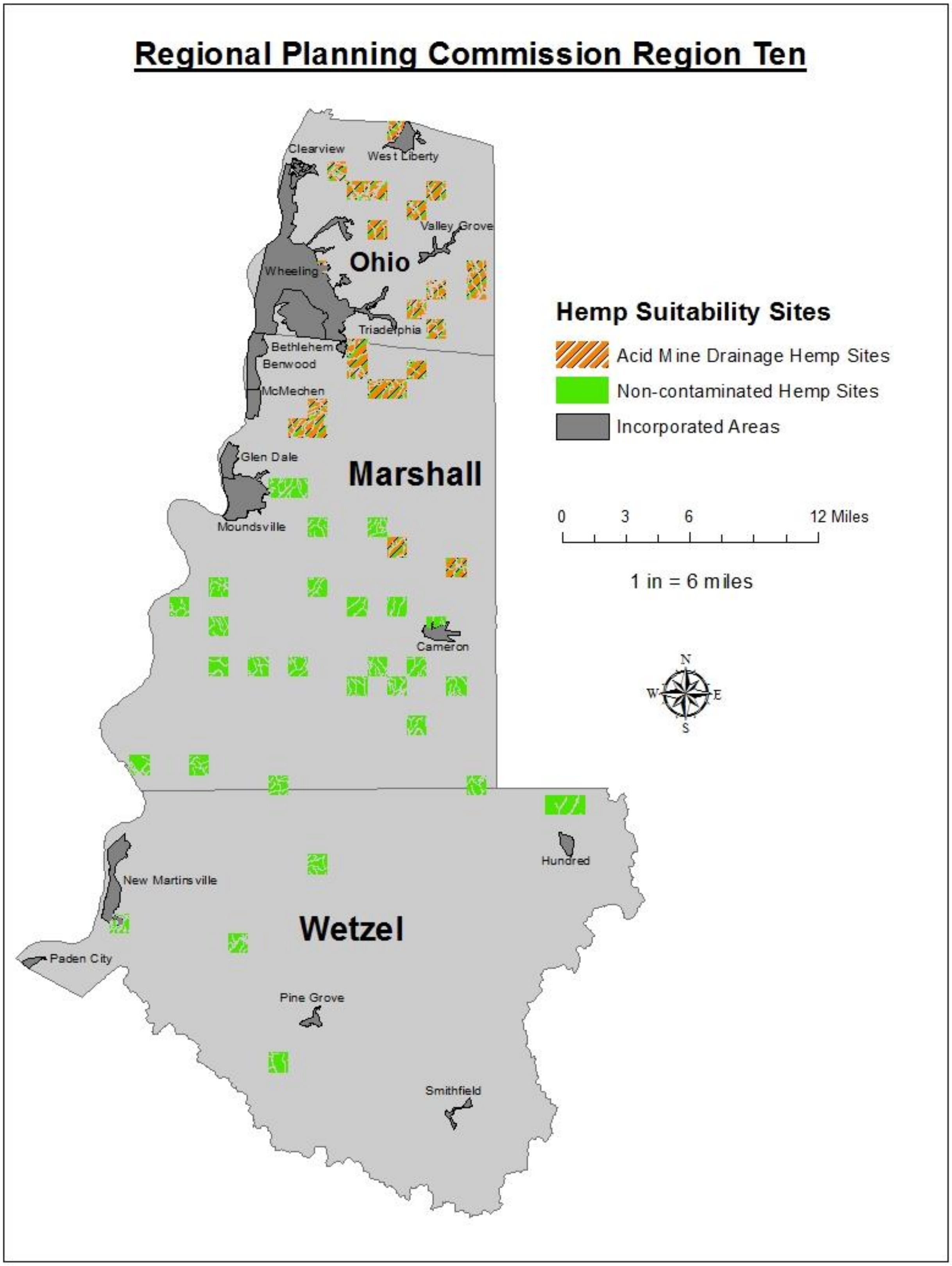

Figure 34 - Hemp Suitability Sites- Region Ten.

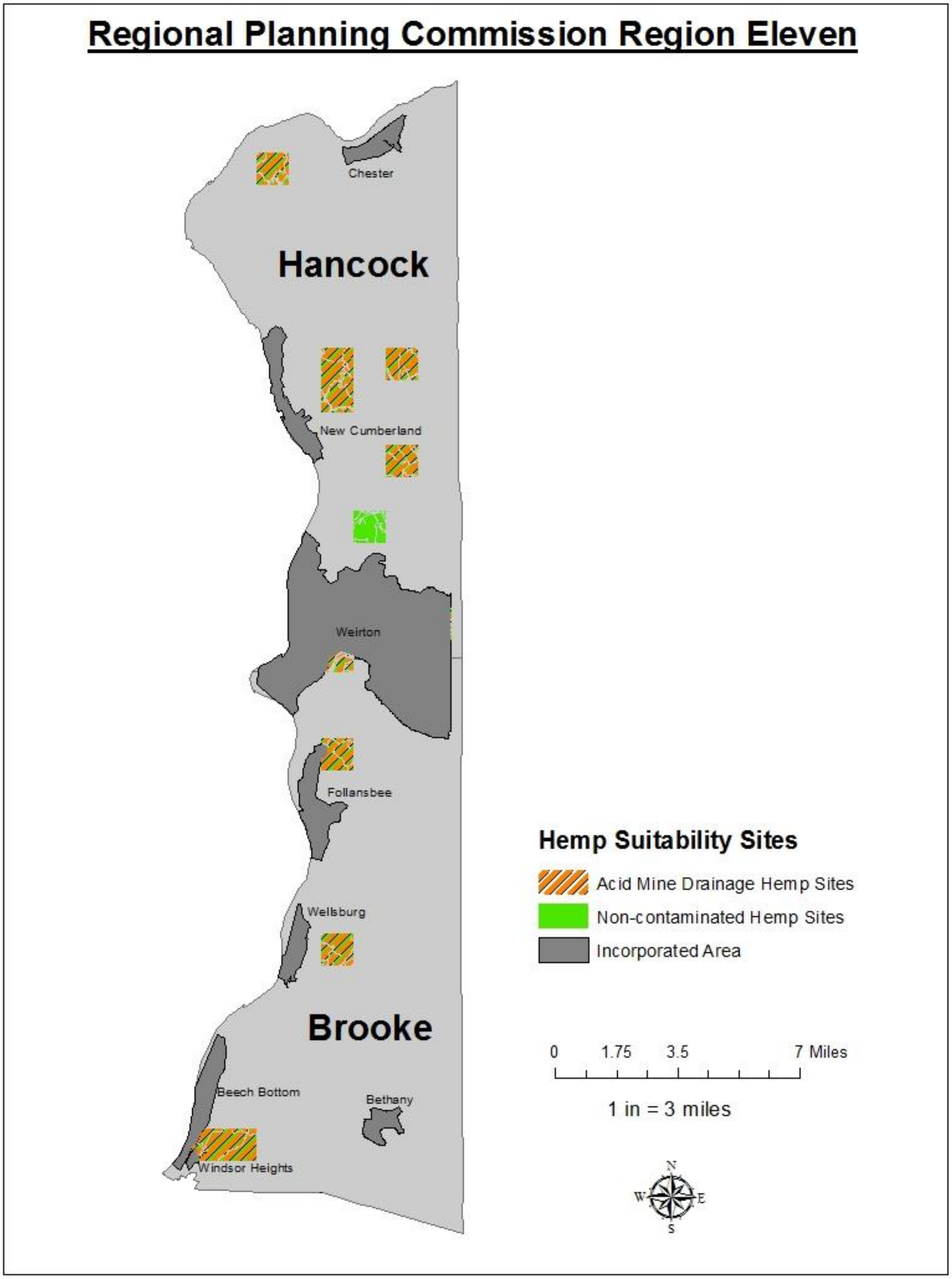

Figure 35 - Hemp Suitability Sites- Region Eleven

CHAPTER 5

CONCLUSION

While searching for a way for West Virginia to sustainably develop, hemp fiber cultivation was explored for its rich industrial uses and the environmental benefits derived from hemp cultivation. A general assumption was that hemp cultivation areas would be plentiful in West Virginia because of the favorable climate and existing vegetation cover, which has proven not to be the case. A hemp fiber suitability study has not been performed on West Virginia before on this scale and therefore adds to the general scientific knowledge by identifying more opportunities for further research and development. While hemp is legal to cultivate in West Virginia, this model has shown which areas and which LULC classifications allow hemp cultivation to be focused upon in order to reach an industrial level, identifying possible contamination sites that could be used for non-consumer based goods and further research into hemp's phytoremediation of acid mine drainage areas. The study began by asking three interrelated questions: where can industrial hemp fiber cultivation sites be found, how does current land use classification affect the availability of industrial hemp cultivation sites, and in which suitable sites is there a possibility of contamination due to acid mine drainage.

The answers to the questions were found in the land use conflict indicated by the three layers according to LUCIS classification. The results were surprising in that out of the 15,384.32 acres in West Virginia, only 23.48% agricultural capacity is available to cultivate hemp fiber according to the binary analysis. This percentage becomes even smaller dropping down to 2.89% when the urban layer was applied. The change of hemp suitable sites from the agricultural layer to the urban layer shows the power and influence that planning has over the industrial enterprise. Additionally the creation of the hemp suitable sites from the urban layer lowers the percentage by three tenths to 2.71%. From the 2.71% of available hemp cultivation sites, non-contaminated and contaminated, with potentially acid mine drainage contaminated hemp sites. Additionally, the hemp contaminated layer acreage indicated that only 1.28% percent of the state that is potentially capable for environmental reclamation efforts through phytoremediation using hemp cultivation.

The hemp suitability model was a success because it does prove that West Virginia has tremendous potential which can support a hemp based industries to operate. Planning has an important role in developing hemp cultivation based industries as evidenced in the urban layer decrease of available hemp cultivation sites acreage lost from the agricultural layer potential. Safety and welfare concerns about consumer hemp based commodities directs that these sites are located near non-contaminated hemp cultivation sites. Hemp when cultivated on potential acid mine drainage sites may be better suited to a more industrial market, energy generation purposes, or strictly for phytoremediation. However there may be some critics claiming more pollution for the use of acid mine drainage hemp for energy production. Consider this, that coal has been used for centuries for energy production and recent advances of scrubbing technologies have improved emissions quality. New energy production centers will have the advantages of modern pollution scrubbing technologies, while at the same time supplying the needs of rural Appalachia with electricity in more decentralized way, using locally environmentally sustainable produced materials, and employing local workers across all economic sectors.

The areas that do not presently have acid mine drainage potential can still be used to encourage industry as well. As stated earlier in the literature review, hemp has an amazing and lengthy list of uses already consumed albeit unknowingly in the consumer market. West Virginia can easily open the market for more employment by helping to advocate hemp based industries. The source of change has to come from the legislators, who should explore and fund the cultivation of hemp and the planners who help facilitate change by inclusion of hemp cultivation in their comprehensive plans. While the cities represented in the final maps are the incorporated areas of West Virginia, there may be local communities not represented that could utilize this information to help facilitate urban growth and augment their tax base to improve their communities.

This model does have some limitations associated with the scale of the results. The first limitation of the model is the scale of the climatological data. The data collected from NCDC are the averages from the eighty-year period and was subdivided by the number of years and the number of months in each year. The results are useful in determining climatic trends, but it does not explain the emergence of unfavorable micro-environments to hemp cultivation. Local planners ought to use local data in comparison to the agronomic factors described earlier. The second limitation is the scale of the analysis itself, while useful on a state scale, it may not accurately represent what is actually present at the site. Local areas and planners can best use the hemp suitability data, comparing to their local parcel map. The lack of a state-wide parcel dataset prevented further analysis to reach the local level. The identification of acid mine drainage sites shows only the potential of the site to be contaminated. Therefore, each site should be ground proved and tested for any possibility of acid mine drainage contamination and/or of any conflicting land use that would invalidate the suitability of that site for hemp cultivation.

West Virginia has an opportunity to grow a sustainable industry that would only improve the quality of their lives by providing employment and their environment through phytoremediation. The legislation legalizing hemp cultivation has been approved and now that the possible hemp cultivation sites have been identified, all that remains is for planners to accommodate and encourage this type of economic growth in their respective regions, through their comprehensive planning. Hemp cultivation in Appalachia may indeed be green gold and the key to creating a more economically viable future, ensuring sustainable development, while preserving the wild and wonderful environment that is West Virginia.

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Appendix A

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Office of Research Integrity
Institutional Review Board

March 26, 2015

Delbert Christopher Cannoy
1115 Mc Connell St.
Ashland, Ky 41101

Dear Mr. Cannoy:

This letter is in response to the submitted thesis abstract entitled *"A LUCIS Model of the Optimum Growing Conditions for Industrial Hemp Fiber Cultivation for Biomass Economic Processing and Potential Phytoremediation Sites in West Virginia."* After assessing the abstract it has been deemed not to be human subject research and therefore exempt from oversight of the Marshall University Institutional Review Board (IRB). The Code of Federal Regulations (45CFR46) has set forth the criteria utilized in making this determination. Since the information in this study does not involve human subjects as defined in the above referenced instruction it is not considered human subject research. If there are any changes to the abstract you provided then you would need to resubmit that information to the Office of Research Integrity for review and a determination.

I appreciate your willingness to submit the abstract for determination. Please feel free to contact the Office of Research Integrity if you have any questions regarding future protocols that may require IRB review.

Sincerely,

Bruce F. Day, ThD, CIP
Director

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Vita

Delbert Christopher Cannoy

Education

Marshall University Graduate School
Huntington, West Virginia
Master of Science- December 2015
Major: Geography
Certificate: Advanced Geospatial Information Science

Marshall University
Huntington, West Virginia
Bachelor of Science – May 2013

Major: Geography
Minor: Geospatial Information Science

Work Experience

Marshall University 08/2015 – 12/2015
Graduate Teaching Assistant-Physical Geography
Graduate Teacher of Record-Introduction to GPS

Marshall University 08/2014 – 12/2014
Graduate Teacher of Record-Introduction to GPS

West Virginia Department of Transportation 05/2014 – 08/2014
GPS Surveyor Internship

Marshall University 01/2014 – 05/2014
Graduate Teaching Assistant-Physical Geography

United States Army 10/2004 - 3/2008
CBRN Supervisor and Supply Logistics Specialist.

Affiliations

Gamma Beta Phi
Gamma Theta Upsilon-International Geographic Honor Society
Golden Key International Honor Society

General Skills

Microsoft Products: (Word, Excel, PowerPoint, & Visio)
GIS and GPS software: (ESRI platforms-ArcMap, Arc Pad, and Erdas Imagine)