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## The Paradox of High Greenness and Poor Health in Rural Central Appalachia

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### Abstract

While many studies have found positive correlations between greenness and human health, rural Central Appalachia is an exception. The region has high greenness levels but poor health. The purpose of this commentary is to discuss this paradox in the context of rural Central Appalachia and surrounding regions. We provide the following possible explanation for this paradox: three sets of factors overwhelming or attenuating the health benefits of greenness. These include environmental (e.g., steep topography and lack of accessible, high-quality green spaces), social (e.g., chronic poverty, declining coal industry, and limited access to healthcare), and psychological and behavioral factors (e.g., substance misuse and mental health barriers). The influence of these factors on the expected health benefits of greenness should be considered as working hypotheses for future research. Policymakers and public health officials need to ensure that greenness-based

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Authors Contribution Statement

Jiaying Dong and Matthew Browning conceived the ideas and designed the methodology; Jiaying Dong, Matthew Browning, Aaron Reuben, and Olivia McAnirlin led the writing of the manuscript. Ray Yeager, Shuai Yuan, Claude Stephens, Mildred Maisonet, Kuiran Zhang, Jaime E. Hart, and Peter James reviewed and discussed the results. All authors contributed critically to the drafts and gave final approval for publication.

Conflict of Interest

The authors declare no conflicts of interest in this research.

interventions account for contextual factors and other determinants of health to ensure these interventions have the expected health benefits.

## Keywords

greenness; natural environments; Appalachia; health determinants; greenness-health paradox

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## 1 Introduction

Numerous studies have demonstrated positive correlations between exposure to greenness (urban parks, forests, and other vegetated areas) and human health (Akpınar et al., 2016; Browning et al., 2022a; Nguyen et al., 2021). Such improvements extend to physical health (Leng et al., 2020; O’Callaghan-Gordo et al., 2018; Parmes et al., 2020), health-related behaviors (Klomp maker et al., 2018), and mental health (Astell-Burt and Feng, 2019). Many of these beneficial associations have been observed in urban contexts. Although a 2022 review found the relationship between green space and health was more pronounced in urban areas than less urban areas (Browning et al., 2022b), greenness in some rural cases has also been reported to positively associate with health outcomes, such as better mood (Roe and Aspinall, 2011) and lower obesity rates and higher physical activity levels (Villeneuve et al., 2018), among others (Nowak et al., 2014).

Nonetheless, the United States Appalachian region has complex and paradoxical greenness and health relationships. This region, particularly rural Central Appalachia and its surroundings, has high residential greenness levels and poor health. This region extends from southwestern New York to northeastern Mississippi, covering approximately 205,000 square miles and 420 counties in 13 states (Boettner et al., 2014). The Central Appalachian subregion includes mountainous areas of southern Ohio (OH), western Maryland (MD), West Virginia (WV), western Virginia (VA), eastern Kentucky (KY), eastern Tennessee (TN), and western North Carolina (NC) (Figure 1). Abundant forests dominate many of these landscapes, occupying approximately 70% of the land cover (Sickle, 2001). Meanwhile, the health of residents in rural Central Appalachia is among the worst in the nation despite the expected health benefits of the region’s abundant natural resources (Woolf et al., 2019). This commentary explores the factors in rural Appalachia that could influence and explain this paradoxical relationship between greenness and health based on a summary of existing literature and research.

## 2 Health and Greenness in Rural Central Appalachia

Appalachia consistently presents worse health outcomes than the rest of the U.S. Specific concerns include heightened incidence of lung disease, cancer, cardiovascular disease, mortality, and other health-risk behaviors such as substance misuse (Blackley et al., 2012; Moody et al., 2017; Singh et al., 2017). Diseases of despair are especially common. These include three main causes of morbidity and mortality: drug overdose, suicide, and alcoholic liver disease. Notably, the 2015 mortality rate of diseases of despair in Appalachia was 37% higher than in non-Appalachian regions (Meit et al., 2017). Overdose mortality rates in Appalachia exceed the rest of the nation by 65%. WV and KY lead diseases of despair

mortality rates for adults, followed by OH and MD. Regarding all-cause mortality, rates increased by 5% in Appalachia between 1999 to 2015, while they decreased by 10% in non-Appalachian states (Meit et al., 2017).

Within Appalachia, rural Central Appalachia (Figure 1) stands out for particularly high rates of respiratory outcomes (DeBolt et al., 2021). For instance, the prevalence of chronic obstructive pulmonary disease (COPD), a type of lung disease, has the highest national rates in WV (11.9%) and KY (11.1%), while TN ranks fourth (8.6%) (Centers for Disease Control and Prevention, 2022). Similarly, the lung cancer mortality rate in KY (83.2 per 100,000 people) was the highest in the nation in 2019. WV and TN are ranked third and fourth, respectively (Visualizations, 2022). Central Appalachia also experiences heightened incidences of other chronic diseases and premature mortality related to cancer, cardiovascular, and respiratory diseases. Heart disease and cancer are the two leading causes of death (244 and 225 per 100,000) in Central Appalachia, followed by lung cancer and COPD (Krometis et al., 2017).

At the same time, Appalachia is renowned for its abundant natural resources, including timber, salt, oil, iron, and coal (Krometis et al., 2017). Over two-thirds of Central Appalachia is forested, one-quarter is agricultural or pasture, and only three percent is developed areas such as residential, commercial, or industrial land cover (Krometis et al., 2017). Based on remote sensing imagery, high greenness levels and tree canopy cover are seen in eastern KY, WV, and western VA (Becker et al., 2022; Wong et al., 2022). The natural areas of Appalachia are also heavily visited for the mountain scenery and outdoor recreation, such as hiking. From 2005 to 2014, more than 173 million people visited National Forests in this area (Boettner et al., 2014). In addition, the Appalachian Trail runs through this region and attracts three million hikers yearly (Conservancy, 2022), although visits among residents may be much briefer than tourists (Yahner et al., 1995). Overall, people in this region could theoretically be expected to have greenness exposure and derive health benefits via direct use. These potentially high nature access and visitation estimates provide further evidence for the paradoxical relationship between greenness and poor health in this region.

### 3. Explaining the High Greenness-Poor Health Paradox

We propose three domains of factors that explain the paradox of high greenness and poor health in rural Central Appalachia: social, environmental, psychological, and behavioral. Environmental factors refer to unexpectedly low greenness access and visitation rates among residents, poorer than expected greenness quality, as well as forest loss, fragmentation, and topographical barriers. Social factors include poverty, coal mining employment, limited healthcare access, food deserts, population change, high disability rates, and lower educational status. Psychological and behavioral factors encompass negative perceptions towards healthcare, varying views on nature, and substance misuse. When combined, these domains of factors may strongly attenuate the health benefits of living in areas with high greenness, or they may overwhelm the health benefits that would otherwise be observed in areas with high greenness (Figure 2). For example, inadequate education and entrenched poverty may overwhelm the health benefits of greenness. Meanwhile, low-quality greenness

and rugged topography may attenuate the health benefits of greenness. We explain each domain of factors next.

### 3.1 Environmental Factors

The topography in rural Central Appalachia may represent a fundamental obstacle to the health benefits of greenness. Many rural Appalachian communities are located in steep mountain valleys, surrounded by narrow and twisting roads that are heavily used by trucks and machinery. The dangerous road conditions can impede the flow of pedestrians and bicyclists to transit to recreational destinations (Jones et al., 2014). Mountainous terrain also adds barriers to physical activity, demanding high fitness levels that could present barriers to residents struggling with health conditions, being overweight/obese, or having physical disabilities (Hege et al., 2017). Topographical boundaries can further segregate residents (Wewers et al., 2006), limiting outdoor gathering and recreation that otherwise provides health-promoting social interaction. The challenging and rugged terrain may provide little access for outdoor recreation in the abundant forest land when trails are absent. Further, although there was an increase in forested acres from 1950 to 2000 in Central Appalachia, this increase occurred mainly on privately owned properties, which are generally inaccessible to the public (Liu et al., 2010). When green areas are open to the public, they may require long drives. For example, in a review of communities in western NC, 16 towns were found to have sufficient parks and playgrounds but low walkability scores (Hege et al., 2017). Poor walkability and poorly designed communities in rural Appalachia (Summers et al., 2020) may provide geographic barriers to accessing outdoor spaces for physical activity and subsequent health benefits. Even semi-urban residential greenness in the region may not be accessible to residents due to a lack of public sidewalks and parks (Swanson et al., 2013).

Meanwhile, while Appalachia has world-renowned natural amenities, a recent survey found that nearly half of the visitors to these and other tourist destinations did not reside in the region (Ezzell et al., 2020). This finding may represent unexpectedly low visitation rates among many residents. Interestingly, the estimated availability of recreational lands in Appalachia was one-third of the nationwide average in 2010: 2,720 persons/km<sup>2</sup> in Appalachia vs. 987 persons/km<sup>2</sup> nationally (Liu et al., 2010). Therefore, this region may experience much higher demands for public lands than other areas of the country, leading to decreased visitor experiences and derived health benefits.

Additionally, many green areas in the region may be unexpectedly low-quality for outdoor recreation. While the region includes the most biodiverse temperate forests in the U.S., it is also a significant source of resource extraction (Maigret, 2020). In the Cumberland Plateau in eastern KY, large-scale surface coal mining has increased the homogenization of landforms, leading to irreversible habitat loss and forest fragmentation (Maigret, 2020). Forest fragmentation is also observed in some areas of western NC, where agricultural cover types are interspersed with forest cover, fragmenting the landscape into small patches and reducing the amount of interior forest where outdoor recreation by residents might occur (Wear and Greis, 2002). Mountaintop removal coal mining affects residents' access to recreational space by destroying and polluting natural lands and streams (Cordial et al.,

2012). Locations affected by mining, as well as others in the region (i.e., private yards and public lands effectively used as junkyards), may not provide “cues to care” that translate to attractiveness and cultural values (Nassauer, 1995). Residents may associate healthy trees, soil stability, and species diversity with naturalness, aesthetics, and recreational benefits (Kendra, 2001). As such, dead or dying trees and eroding soil on public and private lands may not motivate recreational use and subsequent health benefits.

### 3.2. Social Factors

Numerous social factors drive the poor health outcomes in Central Appalachia and surrounding regions, which may overwhelm the expected health benefits of greenness. Entrenched poverty has been a concern in rural Central Appalachia since the nation’s founding (Robinson, 2015). Although the poverty rate in Central Appalachia has decreased from 43% in 1960 (Deaton and Niman, 2012) to 22% in 2020 (Pollard and Jacobsen, 2022), it remains much higher than the nationwide average of 13%. Socioeconomic deprivation is one of the most important risk factors for poor health in the US (Braveman and Gruskin, 2003), which can be attributed to health behaviors, access to predominantly unhealthy food, and limited healthcare resources among the poor. Understanding the reasons for poverty remains an active area of investigation. Still, putative contributors include feedback cycles of chronic stress, physically taxing occupations, health behaviors (e.g., alcohol and tobacco consumption), and lack of access to healthy living infrastructure, including healthy food and healthcare resources.

Limited healthcare access is also associated with the poor health status of rural Central Appalachian residents (Smith and Holloman, 2011). A shortage of healthcare resources in these communities is reflected in the lack of insurance coverage, special care providers, cost concerns, and long waits for outpatient visits (Huttlinger et al., 2004). Local healthcare utilization is low (McGarvey et al., 2011), and healthcare service utilization disparities are driven by factors such as income, education, and gender (Bush et al., 2014; Hendryx, 2008; Thompson et al., 2021; Wilson et al., 2012). Residents face additional healthcare access challenges related to geographic isolation, limited transportation options, and insufficient technology infrastructure (DeBolt et al., 2021; Smith and Holloman, 2011). Due to a lack of healthcare investment, shortages in healthcare facilities and providers remain a challenging issue in the region (Figinski and Troland, 2022), overwhelming public health systems despite the small number of patients (Christian et al., 2010; Cronin, 2023).

Food deserts further impact residents’ health in parts of the region (Hardin-Fanning, 2013; Miller et al., 2016; Mulangu and Clark, 2012). The availability of affordable, healthy, and fresh food is a strong influencer of dietary patterns (Schoenberg et al., 2013). However, food insecurity is positively associated with poverty rates, including in some regions of Appalachia (Bletzacker et al., 2009). Inadequate food access and increasing food insecurity could influence eating patterns, making residents more susceptible to obesity, diabetes, and other health problems. Rural residents are also isolated from urban centers with healthy food outlets and lack beneficial social and living resources, which may contribute to substandard diets and fewer positive health behaviors (Hoogland et al., 2019; Lutfiyya et al., 2012; McGarvey et al., 2011).

Population change further negatively impacts the population-level health status of the Appalachian Region. This region suffered low population growth between 2010 and 2020 (Pollard and Jacobsen, 2022). In addition to high mortality and low birth rates, out-migration is responsible for population declines and demographic shifts. Young residents have led out-migration since around 1990 (Obermiller and Howe, 2000). Simultaneously, rural central Appalachia is becoming a destination for lower-income, blue-collar migrants with lower levels of formal education and older retirees (Wear and Greis, 2002). Approximately 20% of Central Appalachia residents are 65 and over (United States Census Bureau, 2021). These large shares of the elderly and lowering shares of the young could partly drive the poor population-health statuses observed in the region.

Additionally, Central Appalachia is within a “disability belt” - a geographic cluster with a high prevalence of disability (McCoy et al., 1994). People living with disabilities are four times more likely to report worse health than people without disabilities (Altman and Bernstein, 2008). The disability rate in Appalachia reaches 16.2% (United States Census Bureau, 2022), with Central Appalachia having the highest rate of 23.8%. People with disabilities also visit natural outdoor spaces less frequently (Corazon et al., 2017) and potentially receive fewer benefits from any available residential greenness.

Inadequate education in rural Central Appalachia is a significant cause of low employment opportunities and another driver of poor health status. In 2020, the percentage of people with a bachelor’s degree or higher in eastern KY and the surrounding areas was only 15%, much lower than the national average of 33% (Pollard and Jacobsen, 2022). Central Appalachian students have minimal opportunities for digital resources, advanced education, and community support for educational achievements (Statti and Torres, 2020). Following the lack of education, health education is absent in rural Central Appalachia leading to potential deficient health literacy and unhealthy lifestyles (Raghupathi and Raghupathi, 2020). Importantly, the scarcity of health education may be a root cause of insufficient advocacy for green space as a health-promoting factor, exacerbating health disparities.

Finally, the coal extraction industry in rural Central Appalachia and its by-products are hazardous to residents’ health. About 27% of the coal produced in the United States comes from Appalachia (U.S. Energy Information Administration, 2022). The extensive mountaintop mining devastated Central Appalachia and the health of surrounding communities. Although the coal industry and employment in the region have sharply declined in the past decades, its impacts on local population health endure. Miners are exposed to coal dust and toxic silica dust, contributing to the “black lung disease” (Hendryx, 2015; Hendryx and Ahern, 2011; Shriver and Bodenhamer, 2018). Residents in mountaintop mining communities experience significantly worse health than those in rural non-mining areas (Hendryx, 2015; Hendryx and Ahern, 2011).

### 3.3. Psychological and Behavioral Factors

Psychological and behavioral factors may also overwhelm or moderate the health benefits expected from greenness in Central Appalachia. For instance, the high concentration of economically disadvantaged White populations extends to negative perceptions towards healthcare, contributing to worse health. White counties with high poverty rates relate to

an endemic “white Appalachian identity” (Kusmin, 2013). Appalachian whiteness has been stigmatized as “hillbilly” culture, a racialized social system that distinguishes them and their perception of health behavior and healthcare utilization from other White Americans. Furthermore, the stigma of seeking help in mental health services may prevent residents from receiving proper treatment and participating in food assistance programs (Witt and Hardin-Fanning, 2021). Many residents prefer self-treatments for depression or share prescriptions rather than seeking medical help (Huttlinger et al., 2004).

Trust in spiritual prescriptions can also influence residents’ use of healthcare services and health status. Deeply religious Appalachian residents may prefer to trust God over clinical and scientific norms of cancer diagnosis and seek less aggressive medical care (Behringer and Krishnan, 2011). Relatedly, residents may seek religious healing practices outside the medical realm for mental health issues (Keefe, 2014). A counter-example is evidence that increased religiosity and spirituality may be related to *less* cigarette smoking and other negative health risk behaviors among some Appalachian pregnant women (Jesse and Reed, 2004).

Interestingly, different uses and attitudes toward natural environments have been observed between multigenerational residents and newcomers. Multigenerational residents view nature as an economic resource in contrast to newcomers viewing nature as a source of recreational pursuits (Welch-Devine et al., 2022). A study in Western NC found that 40% of the multigenerational residents had livelihoods dependent on natural resources (e.g., logging, hunting, farming) compared with only 28% of newcomers (Welch-Devine et al., 2022). Similarly, 51% of multigenerational residents described themselves as “often” engaging in recreational activities in the natural environment, while 75% of newcomers did. From a multigenerational population, rural Central Appalachian residents may hold beliefs and engage in behaviors that translate to fewer or weaker health benefits from greenness than newcomers.

In addition, substance use, which encompasses the use of illegal drugs, misuse of prescription, excessive alcohol use, and potential consequences of substance use disorder (SUD) (Rowe and Liddle, 2003), is rampant in rural Central Appalachia (Moody et al., 2017). Substance use and unemployment are closely related (Thornton and Deitz-Allyn, 2010), and can translate to social disadvantage and poor health. Lastly, outside settings like national parks or wooded areas may offer secluded places for substance use among young adults (Fadanelli et al., 2020), preventing other residents from visiting them.

#### 4. Discussion

Rural Central Appalachia presents a paradox in the nature-health literature: an area with high greenness and poor health. Like many places in the world, resident’s health is derived from the region’s social and historical backgrounds. Poor health status is considered a result of local industrial make-ups, geographic isolation, lower economic status, limited healthcare access and utilization, and high-risk health behaviors, among other factors. Still, the causal linkages between sociocultural factors and human health are unclear (Gohlke, 2020). We propose three domains of factors that may explain the paradoxical relationship between



greenness and health in this region: environmental, social, and psychological/behavioral. Considering the magnitude and prevalence of these factors to poor health, the health benefits of residential greenness are likely overwhelmed or attenuated. This explanation is our working proposition to explain the high greenness and poor health paradox.

We call for research in rural Central Appalachia and other areas of the world exhibiting this paradox. While we are unaware of investigations on where else this paradox may exist, discovering such places would greatly help us understand place-based contextual factors that moderate the possible health benefits of greenness. One possible area is northeast China (i.e., Heilongjiang and Jilin Provinces), which has high greenness levels (Chen et al., 2022) and cardiovascular disease rates (Su et al., 2022). Many others are expected to exist.

We also recognize that other hypotheses may explain this paradox. One study in Shanghai, China, found that low-income people with heavier workloads had limited recreation time in nature (Xiao et al., 2021), which may limit the health benefits they obtained from greenness. This barrier may also limit greenness exposure and related health advantages among Central Appalachian residents. To investigate this explanation, research could determine the value of leisure-based time in green areas relative to incidental (i.e., during work) and indirect (i.e., views from cars or windows) exposure to greenness (Beery et al., 2017; Cox et al., 2017; Maddock et al., 2022). It's possible that living in a green area but rarely partaking in outdoor leisure activities offers few pathways between exposure, mental and behavioral health, and health outcomes. In rural environments with substantially lower noise, heat, and air pollution levels for which greenness is protective, surrounding greenness could have relatively weaker benefits than urban areas (Browning et al., 2022c). Further, homogenous natural forested areas combined with low population density and steep terrain may offer relatively few outlets or motivations for intentional exposure. Evidence from Australia suggests intentional exposures are more frequent among residents in better health, suggesting that health status may act as both an outcome and barrier to greenness exposure (Cox et al., 2017). The interactions between exposure type, health status, and environmental quality are understudied but could explain variations in the health benefits of greenness across populations. Another factor to consider is how limited transportation networks constrain green space use due to the rurality of Central Appalachia and similar areas (Choi et al., 2019).

An alternative or synergistic explanation to the paradox is that a minimum threshold in basic social and material necessities may need to be met before the mental and behavioral benefits of greenness are realized. Such thresholds have been observed in other health and socioeconomic status studies, specifically income inequality (Pickett and Wilkinson, 2015). For example, Kondo and colleagues (2012) found stronger effects of inequality on mortality risk among cohort studies in countries with Gini coefficients  $>0.30$ . We are unaware of studies that test whether the health benefits of greenness are only observed above basic living standards. Discussions of the impact of living standards on health (i.e., Pickett and Wilkinson, 2015; Wilkinson, 2002; Wilkinson and Pickett, 2006) are largely absent from the greenness and health literature. This explanation can be tested alongside our primary explanation for the paradox.

Because this paradox exists, policymakers should understand residents' health and recreation needs before adopting nature-based interventions, particularly among rural and disadvantaged groups. Green space planning and design practitioners should consider local conditions and design landscape features that are accessible, comprehensible, and diverse, with well-maintained infrastructure and facilities to support the recreational preferences of less physically mobile groups (Nilsson et al., 2010; Wen et al., 2018). Funding priorities should be allocated to health-promoting design projects and park management systems that strive to meet the demands of all residents. In contrast to urban settings, the rural nature of Appalachia remains a challenge for policymakers seeking to increase the variety of recreational green space beyond forests. Communities may desire landscapes and amenities beyond forests for outdoor recreation. However, the best action may involve the community as a stakeholder to share what nature experiences they would use and enjoy within their community. Subsequently, policies may focus on expanding green space variety and lowering the distance and time required to access these spaces. In addition to health-related projects, the cooperation between the public health departments and local community stakeholders may help relieve the stress from local health needs and create opportunities to develop healthy living environments for residents. With the increasing aging population and demand for transportation, public transit programs and services should be strongly considered (Appalachian Regional Commission, 2020). Other policy recommendations may include increasing community participation in policy enactment and involving educational and religious institutions as community partners to encourage beneficial interactions with the natural environment. Ultimately, we believe the extensive local greenery in places like rural Central Appalachia will confer stronger health benefits if the contextual factors and needs of residents related to health-promoting outdoor recreation are better understood.

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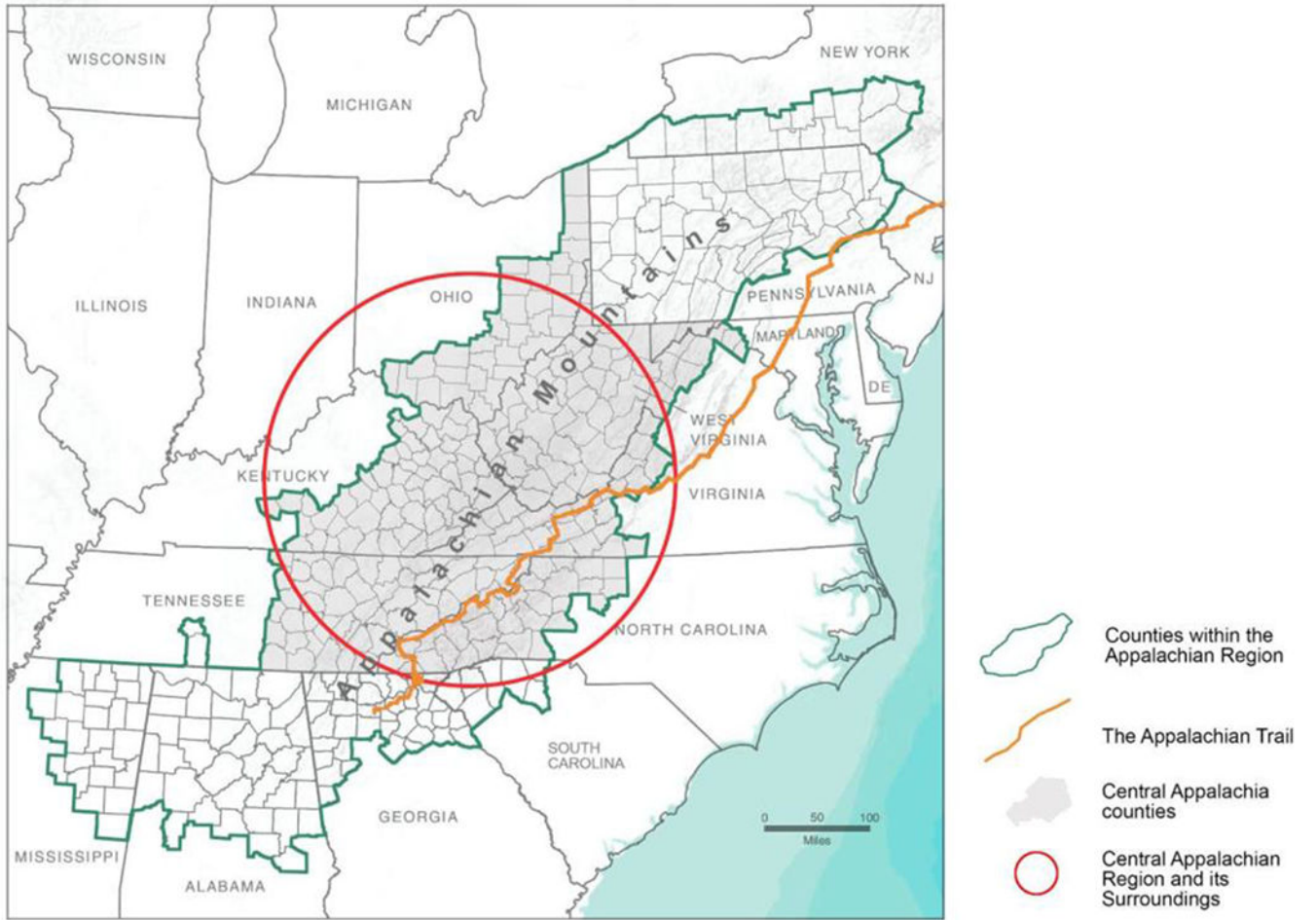
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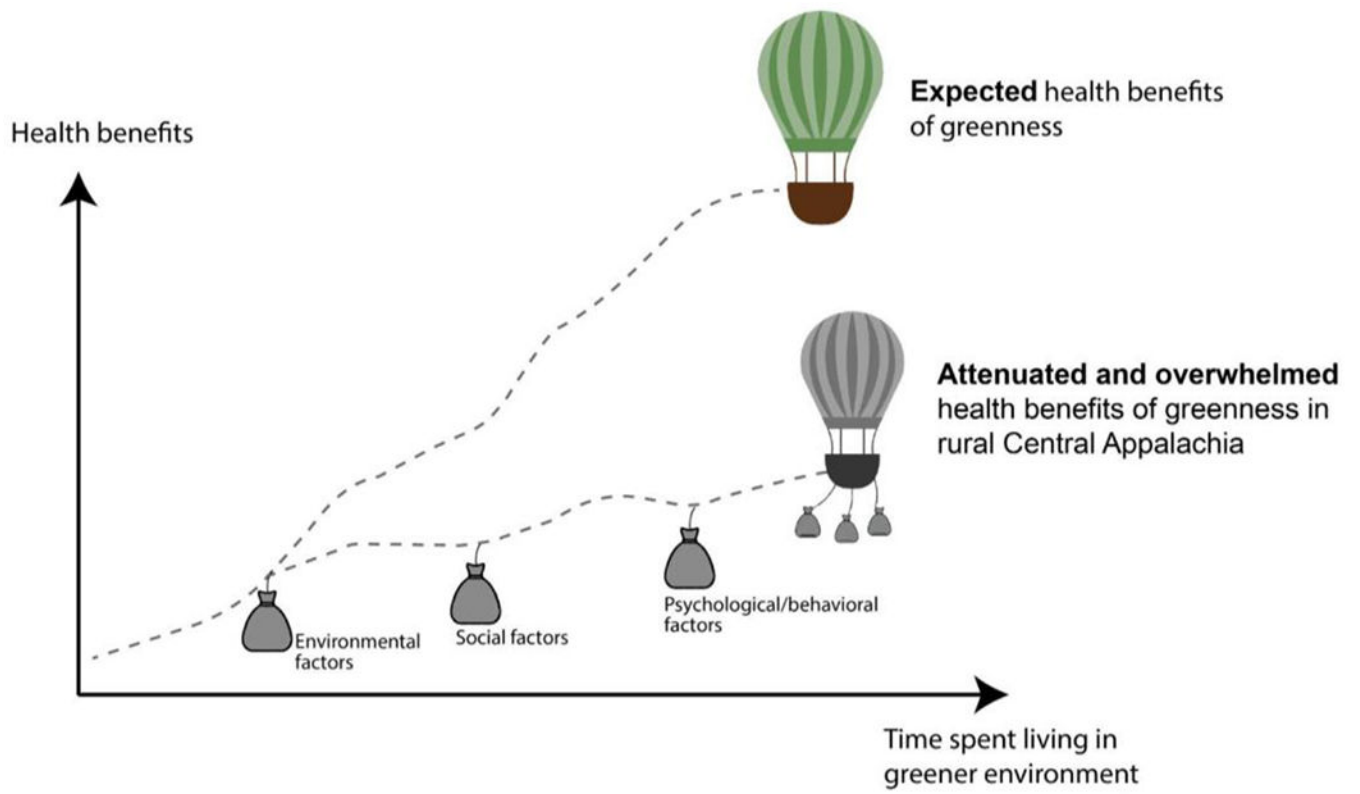
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**Figure 1.**  
Map of Central Appalachia and its surrounding regions





**Figure 2.** Domains of factors that may attenuate or overwhelm the health benefits of greenness, thereby explaining the high greenness and poor health paradox in rural Central Appalachia, U.S.