



Working White Paper

Ecosystem Services of the Appalachian Carbon Exchange Project Areas

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Context and Definitions

The Southeastern United States represents a myriad of working lands where agricultural and natural systems interweave with the ecosystems, which are heavily influenced by hydrologic, edaphic, topographic, and climatic gradients. These factors form the nuanced landscapes well beloved by the community. Composed of highly dynamic environments, the lands of Appalachia hold countless values to the people inextricably linked to the working definition of habitat: food, water, shelter, and space. These working lands are majorly held under private control, constituting agricultural applications such as grazinglands, timberlands, and croplands. This illustrative mosaic of Appalachia provides a diverse array of ecosystem services. Within the project area of the Appalachian Carbon Exchange (ACE), we have identified the most prominent of these to be flood mitigation, nature-based recreation, species richness/biodiversity, air quality control and pollination.

Assessments of landowner intentions help guide the development of education and outreach programs that facilitate the protection of ecosystem services embedded in the complex fabric of the quilted landscape. Illuminating a study conducted by the University of Tennessee's Department of Forestry that examines the incentives underscoring nonindustrial private forest (NIPF) landowners for supplying ecosystem services (ES) in the Cumberland Plateau highlights land management objectives for the largely 81% of privately-held forestland of Tennessee¹. Surveyed participants delineated motivations for governing ES supply through socio-demographic characteristics. The findings of the research demonstrate that transparent financial incentives are paramount to the NIPF landowners' conservation of three types of ecosystem services: carbon sequestration (regulating service), water quality (provisioning service), and aesthetics (cultural service). ACE's mission harmoniously aligns with these findings and advocates for clearly defined mechanisms and a grounded operative framework founded on extensive research, acute attention to detail, and cohesive community collaboration. Quality environmental assets are the cornerstone of ACE's operational process and we aim to ensure high-quality, nature-based climate solutions to the Appalachian region.



Through this working white paper, we will continue to refine the classifications for these ecosystem services with our institutional partners. Once finalized, it will serve as the backbone for the measurement and research of these services within the areas enrolled in the Improved Forest Management carbon project.

As demonstrated by FEMA (Federal Emergency Management Agency) through quantifying a calculable market value, ecosystem services are prerequisite to the operation of socioeconomic affairs. A burgeoning practice, this strategy aims to assess the benefits of services in terms of a tangible concept that is inherent to the cohesive functioning of a robust ecosystem². Demystifying the social gains with comprehensive capital assessments facilitates the integration of ecosystem services within a decision-makers process. Through an extensive literature review, the selected ecosystem services analyzed in this paper accurately represent Appalachia's foremost optimized resources and facilitations embedded in the landscape's vertical gradient of dry, forested uplands down to the humid, nutrient-rich lowlands. Highlighting site-specific routine ecosystem services accurately demonstrates the hallmark natural systems of the region.



Flood Mitigation

As observed in recent trends, losses produced by flood waters have increased significantly due to the rise of economic development centered in flood zones³. Damages exacerbated by more frequent extreme weather events (EWEs) are expected to magnify as climate change unfolds. Thus, defining and framing flood mitigation as an ecosystem service that properly assesses the attenuating properties of the service is becoming noteworthy.

Flood control is defined as the management of water flows by natural systems that either mitigate or prevent damages to both the economic assets (i.e. agricultural infrastructure) and lives residing within the floodplains⁴. All ecosystems inherently provide the benefit of flood mitigation but in particular forests, the adjacent shrublands and grasslands, as well as wetlands reduce rainfall runoff. These systems act as a preliminary reservoir for rainwater as it cascades through the leaf and bark structures of the plants, then latterly as a detention mechanism bolstered by the extensive root systems⁵. Reducing the erosional impact of rainwaters through vegetative buffers allows for the groundwater aquifers to recharge as the detained rainwaters percolate through the soils of the ecosystem. Slowed water flows prevent rapid surface water runoff from the landscape, thereby lessening observed peak runoffs, and thus mitigating the catastrophic effects of flood events on the local habitat.



As demonstrated by a NOAA (National Oceanic and Atmospheric Administration) precipitation and flood climatology study, the Appalachian region experiences higher rates of flash flooding due to the conjunction of steep slopes characteristic of the mountainous topography and the geographical proximity to major air moisture sources of the Atlantic Ocean and Gulf of Mexico⁶. Areal flooding, exacerbated by the region's expanding commercial and residential development, is of growing concern as climatic changes escalate the severity of storm systems and the frequency at which they occur. FEMA, the Federal Emergency Management Agency, quantifies the direct market value of flood and storm hazard reduction categorically by habitat type and are priced as:

Urban Green Open Space	\$316/acre/year
Rural Green Open Space	Undefined
Riparian	\$6,052/acre/year
Forest	\$368/acre/year



Nature-Based Recreation

Falling underneath the scope of cultural services, nature-based recreation encompasses a myriad of social benefits. Highlighted as non-material gains, the opportunity of nature-based recreation reaps significant personal ties to one's surrounding landscape and includes cultivating aesthetic ingenuity, core cultural identities, a sense of place, as well as mental and physical health amelioration⁷. Furthermore, providing green space accessibility in historically industrialized areas offers community members healthier cortisol profiles, a key stress hormone.

Refining communities' landscapes to incorporate nature-based recreational opportunities in the patchwork of a developed environment strengthens individual identities associated with the living environment. Operable definitions of a subject's environment are highly subjective to one's known purview and are vastly dynamic, formed by experiences. Uplifting one's natural heritage promotes a sense of belonging underscored by traditional knowledge and associated customs.

A local organization known as Thrive Regional Partnership, represented by a broad coalition of local cross-sector alliances, [produced survey data](#) in 2020 demonstrating the motives and aspirations of community outdoor recreationists within a 16-county cross section of Southern Appalachia. Illustrating conservation target areas that bolster high-demand activities such as hiking, bird-watching, camping, mountain biking, trail running, and horseback riding, the report underscores key takeaways for regional decision-makers.



Chiefly, the report's findings centralize around the social group interactions promoted through outdoor recreation activities that are inherently unions of cooperative participation. Group-oriented opportunities in the Appalachian region include climbing, whitewater rafting, flatwater paddling, and horseback riding. Socially intensive nature-based recreation offers a myriad of socioeconomic benefits to the surrounding community of the less traversed areas of the Appalachian landscape with promises of local economic flourishing stimulated through small business fellowships. FEMA's direct market valuation for the ecosystem service of recreation/tourism is as follows:

Urban Green Open Space	\$1,642/acre/year
Rural Green Open Space	\$601/acre/year
Riparian	\$6,215/acre/year
Forest	\$94/acre/year



Biodiversity

Measuring biodiversity, or biological diversity, presents a multitude of analytical lenses that can assess the variation present on the genetic level upwards to the species level of an ecosystem. Encompassing the spatial and compositional attributes at all scopes of the environment aims to accurately summarize the functionality and resiliency of the ecological community. Biodiversity emphasizes variation in three hierarchies: within species (accounting for genetic and population differences), between species (measuring evenness against total community), and within ecosystems (qualifying biomes or vegetation types) ⁸. Illustrating the multilayered relationship of ecosystems, the complexity of abiotic and biotic interactions, highlights the ecosystem service's quality, quantity, and reliability. Consequently, as the physical, chemical, and biological factors of an ecosystem change, so will the natural processes harbored within the system and, ultimately, the services.

Heralded as a paragon of biological diversity unrivaled by any other region of the country, the southeastern United States claims rich, moist environments that support species variance paramount to the Appalachians interconnected dynamic ecosystems' functionality. Hosting biodiversity hotspots for salamanders, mussels, freshwater fishes, dragonflies, damselflies, crayfishes, amphibians, and plants is the hallmark of the beloved ridge and valley landscape⁹. According to the Center for Biological Diversity, a contemporary freshwater species extinction is plaguing the waterways running through the region's deep gorges and valleys. Periled by threats of pollution, commercial and residential development, logging and extractive mining operations, industrialized agriculture practices, dam construction, and invasive species introduction, extinction looms for more than 28% of freshwater fishes, 48% of crayfishes, and 70% of mussels ¹⁰. Cited as the largest modern mass extinction in North America, the Coosa River in Alabama, with headwaters originating in Tennessee and Georgia, witnessed the eradication of 36 freshwater species prompted by the development of a series of dams ¹¹. Currently, FEMA does not include the ecosystem service of biodiversity within the agency's direct market valuation.



Air Quality

Air quality is the measurement of the ambient atmospheric composition including the chemical, physical, or biological agents that alter the naturally occurring characteristics of the troposphere, the lowest region blanketing the earth's surface. Industrial processes, forest fires, and transportation are the chief sources of air pollutants that alter the naturally occurring atmospheric makeup and dually degrade ecosystems and human health capabilities¹². Three commonly monitored air pollutants, as regulated by the federal legislation of the Clean Air Act instituting NAAQS (National Ambient Air Quality Standard), are sulfur dioxide, nitrogen dioxide, and particulate matter. Representing the byproducts of extractive industries (e.g. paper pulp manufacturing, petroleum refineries, fossil fuel combustion), these air pollutants impede a community's health and well-being. Chronic exposure to irritating air pollutants increases an individual's risk of pulmonary diseases, lung cancer, heart disease, and strokes with short-term exposure increasing likelihoods of respiratory infections, asthma attacks, and acute bronchitis.

Pronounced as the highest elevation along eastern North America, the Appalachians experience nationally recognized high rates of trapped air pollutants fostered by the extreme acclivity of towering mountain tops reaching high altitudes and the region's predominant weather systems. Concurrently, the region experiences some of the highest rates of deposition for nitrogen and sulfur in North America¹³. The area, proving to be an outlier and contradicting national pollutant trends, is confronted with an exponential increase in sulfur dioxides stemming from coal production within the past two decades.



Furthermore, high-elevation soils of the Appalachians are stressed by advanced nitrogen saturation caused by the hazardous levels of ambient airborne nitrogen which in turn permit toxic ions such as aluminum to proliferate within the substrate and induce biological harm on the surrounding aquatic biota and vegetation¹⁴. FEMA's direct market valuation for the ecosystem service of air quality is as follows:

Urban Green Open Space	\$201/acre/year
Rural Green Open Space	Undefined
Riparian	\$254/acre/year
Forest	\$711/acre/year



Pollination

Pollinator species play a critical role in the vitality of agriculture systems. Simply, pollination is the transfer of pollen from an anther to a stigma between flowering plants. Fruit and vegetable crops develop flowers that require the transfer of pollen in order to vegetate the harvestable produce successfully. Root and fibrous crops rely on pollination to bear seeds¹⁵. Furthermore, the biodiversity of endemic flora species present in the forest floors of Appalachia rely on specialized pollinators for survival and render a food supply of nectar and pollen. Extracting the ecosystem service provided by species like bees, wasps, butterflies, moths, birds, and bats shifts the onus onto industrialized, input-heavy agricultural operations¹⁶. Thus, it is increasingly paramount to accurately frame the regulatory balance that exists between the mosaic of the working landscape and the biological counterparts attributed to flourishing food production.

Recent studies have illustrated the level of magnitude pollinator species harness in the synergistic interplay with 88% of all flowering plants and 35% of global food-producing crops being indispensable to pollinators to efficiently germinate¹⁷. Landscape stewardship with integrated pest management (IPM) alleviates the cost inputs for rural farmers, while dually addressing the agricultural run-off inextricable to modern farming practices.



Comprising multi-dynamic habitat types throughout the southeast, ranging from longleaf pine stands to species-rich mixed mesophytic forests, this temperate region boasts crop types emblematic of the area's diverse flora. Poignantly, agriculture based on crop types such as corn, soybeans, cotton, peanuts, tomatoes, peppers, sweet potatoes, tobacco, and blueberries in the southeast are the main drivers of state economies. In 2020 alone, these cash crops generated \$35.4 billion in revenue on an expanse of 49.2 million acres of cultivated land. Crop vitality correlates to the abundance of native pollinators. In particular, the state of Georgia is the nation's top producer of blueberries with a market size of \$348,745,413 in 2021, according to the University of Georgia's Agriculture Extension¹⁸. Pollinated blueberry crops demonstrate superior seed sets, larger fruit sizes, and higher yields. As demonstrated through research by Pollinator Partnership, managing habitat for the promotion of native pollinators holds the potential to increase rural blueberry farmers' profit margins at estimates of \$4,700-\$5,700/acre. FEMA's direct market valuation for the ecosystem service of pollination is as follows:

Urban Green Open Space	\$350/acre/year
Rural Green Open Space	\$350/acre/year
Riparian	Undefined
Forest	Undefined



Discussion

Based in Chattanooga, Tennessee in the foothills of Southern Appalachia, the programs of the Appalachian Carbon Exchange are uniquely positioned to support this intertwined ecosystem network. In general, the working lands of the region are highly coveted for their provisional services, with less consideration given to the other defined ecosystem services such as cultural, regulating, and supporting frameworks that are more challenging to quantify and are often less acknowledged. The process of quantifying and transacting carbon as an ecosystem service begins to open up the consideration of additional services not previously accounted for in the budgetary lens.

The systematic approach to quantifying ecosystem services must inherently weigh and classify the uniquely embedded synergies governing these relationships. Characterizing the scope of these frameworks is typically under-realized. Generally, regional ecological assessments of the working lands of the southeast are low-valued in terms of providing support and regulation of these services ¹⁹. Thus, eliciting a simplification of their dynamic to extrapolate the ecological co-beneficial services granted to the region's residents.

In Appalachia, natural ecological systems are ubiquitously coupled with high-intensive working lands. For example, high upland and riparian areas are typically deemed as conventional timber harvesting areas, but dually are underscored as critical habitat spaces for wildlife. Lowlands converted to pasture fields are intertwined with existing wetlands and ponds while converted agricultural fields utilize irrigation systems to supplement the drylands, facilitating a crucial foraging range for wildlife living in the shouldering grassy and forested riparian zones²⁰. Contrasted to the extensive tracts of federally protected lands in the western United States, the working lands of the southeast lack the bedrock safeguards conserving these tightly intercoupled biogeographic dynamic environments.



Conversely, when the “working landscape” with lower intensities of land use is coupled with immersed natural systems, a vast array of ecosystem services are illustrated, including those that are provisioning, regulating, supporting, and cultural. Quantifying these synergies to illustrate the holistic viewpoint of the working lands aims to accomplish the characteristic values of a robust natural network. Calculated qualifications of these ES provide insight into sustainable land use policy and can construct an operable framework for land stewards working in the Appalachian region. This is a critical objective to meet the needs of production for future generations while continuing to safeguard the natural resources, like soil, water, and biological resources, embedded in the working lands.

Regulatory parameters set to defend rich biological integrity, natural habitat ecosystems, and ecosystem processes in the United States are typically attributed to federally protected lands like parks. These New Deal era legislations increased the nation’s inventory of protected swaths emphasizing the biological diversity as well as other natural, cultural, and recreational applications. Previous assessments of these lands with a lens calibrated to ecosystem services typically place heavy precedence on parameters innate to federally protected lands, such as national parks, and do not encompass the broad portfolio of working land types held in private ownership.

Economic assessments measured under this scope fail to illustrate the accurate depiction of the broad working lands of Southern and Central Appalachia. Areas typically devoted to agricultural and silvopastoral operations lie within the fertile soils of the lowlands, but have traditionally been deemed antithetical to the conservation agenda. Coincidentally, the nature-based carbon solutions ubiquitous to these practices improve the rate of carbon sequestration, responsibly steward water and soil systems, and increase levels of biodiversity and cultural significance. Strategic stewardship rooted in sustainable land use applications maintains the delicate ecological balance of these ecosystem services, while intensive industrial operations create negative externalities hindering the ecological homeostasis of the working lands. These primarily



include nutrient pollutant run-off generated by fertilizers, land conversion depleting natural habitats, influxes of sedimentation and pesticides in local waterways, and increased greenhouse gas emissions²¹.

Overlooking the patchwork of land use change with which working lands lie misrepresents the landscape's context of beneficial and tightly coupled services intrinsic to the multifunctional working systems. Additionally, subtracting anthropogenic manipulations from the land diminishes the ecological role of human interaction with the natural environment. Where uplands are blanketed in forest canopy and dappled with riparian buffers, adjacent to the agricultural lands of Appalachia, regulatory services efficiently manage nutrient-rich runoffs that would otherwise threaten the intricate hydrogeology inherent to the dominant karst landscape. The synergy produced within the relationship between humans and the land is not mutually exclusive and should be actively integrated into thoughtful assessments that aim to both quantitatively and qualitatively define the ecosystem's service.

Furthermore, regulating services provided by the upland forests complement the supporting services, sustaining natural processes, that coincide with protected habitat. These critical ecological services harnessed in these supporting benefits include the vital habitat for pollinator species instrumental to crop viability. This coupled synergistic relationship improves provisional services attributed to observed yields and harvests of the working lands. Low-intensive cattle management on both pastures and rangelands provides additional supporting wildlife habitat with the regulatory services supplementing fire and carbon sequestration. Uplifting these synergistic interplays and mitigating trade-offs target the ecological harmony that encapsulates the multi-faceted ES intrinsically tied to the legacy practices of land use change dating back to the Native Americans that pioneered the ideology of exemplary land stewardship.



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