Ecosystem Services in the Pisgah-Nantahala National Forest Region

Concepts, Estimation, and Application to National Forest Planning

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ABSTRACT

Planning for the management of national forests now requires consideration of the many ways in which ecosystems contribute to human well-being, including by providing goods and services that benefit people economically. The national forest "Planning Rule" and associated directives for implementing it, however, provide only minimal guidance on how to satisfy the Rule's stated intention to ensure the continued delivery of ecosystem services. Several national forests are making first attempts to develop plans in accordance with the Planning Rule, and this entails a good bit of learning by doing. That learning process can be enhanced by applying both a consistent ecosystem services framework to guide the agency's analysis and the use of established and evolving tools for quantifying ecosystem service flows in either biophysical or monetary terms. In this report, we describe such a framework and employ an enhanced "benefits transfer method" to provide an example of ecosystem service valuation for the Pisgah and Nantahala National Forests planning region. By the conservative estimate developed here, the region produces between $14.0 and $50.1 billion per year in ecosystem service value across the 18-county region containing a mix of private and public land. The two national forests themselves contribute disproportionately to this total. This is due to the mix of land uses on the national forests and the relatively greater health of those lands. This information is developed and presented in a spatially explicit way, which enables citizens, federal land managers and private landowners to target land protection and management actions in ways that achieve the greatest potential delivery of ecosystem service value.

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POLICY SETTING

Arguably, what we now call "ecosystem services," including supporting, provisioning, regulating and cultural services are the reason we have our national forests.

The Forest Management Act of 1897 defined the purpose of the (then-named) forest reserves as ensuring adequate provisioning services, notably water and timber. Similarly, the Weeks Act of 1911, which established the Nantahala and Pisgah and other National Forests in the eastern U.S., was passed, in its words,

> …for the protection of the watersheds of navigable streams, and to appoint a commission for the acquisition of lands for the purpose of conserving the navigability of navigable rivers.

Later, the Multiple Use Sustained Yield Act of 1960 declared the policy of Congress to be "that the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, wildlife and fish purposes" – that is, for various provisioning, regulating and cultural services.

Later in the 1960s, the term "ecosystem services" was coined, and in in the early 2000s, the *Millennium Ecosystem Assessment* signaled the arrival of ecosystem services as a powerful organizing framework for understanding the linkages between the health of natural systems and the vitality of human systems worldwide (Millennium Ecosystem Assessment, 2003; Reid et al., 2005). Now that the term exists and a framework has been established, the US Forest Service has adopted "ecosystem services" into its regulations for how we plan for and execute the management of our national forests.

The Record of Decision for National Forest System Land Management Planning (the Planning Rule) presents an important opportunity to improve the stewardship of 193 million acres of public land in the United States (USDA Forest Service, 2012). As stated in the Planning Rule, its purpose is, in part, to ensure that management of the 176 units of the National Forest System

> provide people and communities with ecosystem services and multiple uses that provide a range of social, economic and ecological benefits for the present and into the future. (§219.1(c))

Ecosystem services are defined in the Planning Rule as "benefits people obtain from ecosystems," and it groups these benefits into the "supporting," "regulating," "provisioning," and "cultural" service categories (USDA Forest Service, 2012). In addition, the Planning Rule also requires that the agency "shall use the best available scientific information to inform the planning process (§219.3)."

Eight national forests across the country have been named "early adopters" meaning they will be the first to revise their land and resource management plans according to the new Planning Rule. Several other national forests that had begun or were about to begin their plan revisions under previous guidelines have opted to apply the new planning rule instead. The Pisgah and Nantahala National Forests, for which national forest plans are developed jointly, are among this second group ((USDA Forest Service, 2014). Accordingly, planning for these two national forests must assess and ensure the delivery of ecosystem services.

To date, the Forest Service has considered ecosystem services in its initial assessment document, listing several "key ecosystem services" among the benefits that people obtain from the Pisgah and Nantahala National Forests (USDA Forest Service, Southern Region, 2014). As may be expected at the early stage of plan revision, and particularly with the new rule and new expectations regarding ecosystem services, the information provided in the Assessment is fairly general. It includes, for example, a list of values or benefits mentioned by participants in early planning meetings grouped into two broad categories of ecosystem service: cultural services on one hand, and a combined category for provisioning, regulating and supporting services on the other (see Figure 1, below). This approach could be fine, but because the Assessment does not articulate, and does not seem to have employed, a clear conceptual framework capable of guiding the sort of science-based assessment envisioned in the Planning Rule, the approach produces some problematic results.

For example, Table 22 of the Assessment lists as "Key Cultural Services" several values/benefits, such as "Access," "Economy" and "Family," that are not ecosystem services at all. In the right-hand side of the table, "Economy" appears again, and "Nature/Natural Resources," turns the definition of ecosystem services into a tautology: nature is a benefit that people get from nature.

Table 22. Key words from meeting participants regarding benefits of Nantahala and Pisgah NFs.

Key Cultural Services	Key Provisioning, Regulating, and Supporting Services
Recreation	Health and well-being
Hunting	Timber
Fishing	Clean Water
Hiking	Habitat
Tourism	Clean Air
Camping	Economy
Access	Diversity (biological)
Economy	Nature/Natural Resources
Jobs	Food
Family	Wildlife

Figure 1: Categorization of benefits of the Pisgah and Nantahala National Forests as "Ecosystem Services" (USDA Forest Service, Southern Region 2014, p.94)

In addition, the analysis of ecosystem services is shunted off to various other sections of the Assessment or to other documents entirely. While it makes sense to cross-reference ecosystem services like recreation or clean water [for drinking] with “Assessing Recreational Settings” or “Assessing Soil and Water Resource” (USDA Forest Service, Southern Region, 2014, p. 95), the failure to provide an integrated ecosystem services assessment blunts the potential power and clarity the concept could bring to national forest planning. At a minimum, it seems to fall well short of what the Rule and the Forest Service Handbook require with regard to ecosystem services (USDA Forest Service, 2015).

Objectives of the Study

Given the potential for ecosystem services to provide robust guidance for national forest management and what appears to be a less-than robust start for the Pisgah-Nantahala forest plan revision process, we aim to provide three critical pieces of information in this report.

The first is a more complete conceptual framework than the scant guidance provided in the planning rule and the Forest Service Handbook with regard to ecosystem services. We believe this framework is consistent/compatible with the official guidance while providing more detail to enable planners to fully consider how national forest management, ecosystem health, and human well-being can be linked, assessed and analyzed in the planning area.

Second, we describe replicable procedures based on the well-established “benefits transfer method” that forest service staff and others could use to develop spatially explicit, monetary estimates of ecosystem services provided by national forest system and other lands.

Third are such monetary estimates for the Pisgah and Nantahala National Forest region, namely the 18-county region of western North Carolina that contains the two national forests. Because we tied these estimates to particular places on the map, it is possible to visualize the location of portions of the geographic planning region that provide more or less of various ecosystem services. This, in turn, provides an initial guide to the development of alternative management area definitions that would best protect or allow the restoration of conditions yielding those services.

ECOSYSTEM SERVICES FRAMEWORK

As noted, the idea that people receive benefits from nature is not at all new, but “ecosystem services” as a term of art describing the phenomenon is more recent, having emerged in the 1960s (Millennium Ecosystem Assessment, 2003). Even today, however, the term might be unfamiliar to many people, so we begin with a sample of definitions.

“Benefits people obtain from ecosystems (Reid et al., 2005)” is perhaps the simplest and most commonly heard. In this context, it has the advantage of being the definition adopted for the Planning Rule.

Boyd and Banzhaf (2006) argue that this simple definition is too “ad hoc to be of practical use” in evaluation of impacts on human well-being and offer an alternative that makes ecosystems (goods and) services more directly comparable to other goods and services that people consume. *Final* ecosystem services, they offer, are “components of nature, directly enjoyed, consumed or used to yield human well-being (p. 619).” This definition is particularly helpful when one wants to value ecosystem services in monetary terms. Its focus on final ecosystem services is intended to avoid double counting the value of underlying processes along with the resulting good or service directly enjoyed, consumed or used. Just as one does not buy steel, rubber, upholstery and wiring and THEN a car (one just buys a car), people should think of themselves as buying “drinking water” rather than some volume of water, plus purification services AND THEN purified water. The point is not that the underlying processes are not valuable; rather it is that their value is already included in the value of the final service.

Gary Johnson of the University of Vermont provides a definition that emphasizes that ecosystem services are not necessarily things – tangible bits of nature – but rather, they are the effects on people of those bits of nature. Most importantly, he emphasizes that it is not just WHAT those effects are that matters – it is also WHEN and WHERE they occur. To wit:

> Ecosystem services are the effects on human well-being of the flow of benefits from an ecosystem endpoint to a human endpoint at a given extent of space and time (Johnson, 2010) [emphasis added].

This definition makes clear that it is indeed benefits to people we're talking about. It is a flow or rate of benefit delivery we're talking about. And it is the spatial and temporal context of the flow that's important. Flood control on the other side of the continent is only so interesting when you are stacking sandbags around your own home. And it would be best to have cleaner air before yet another child has developed asthma.

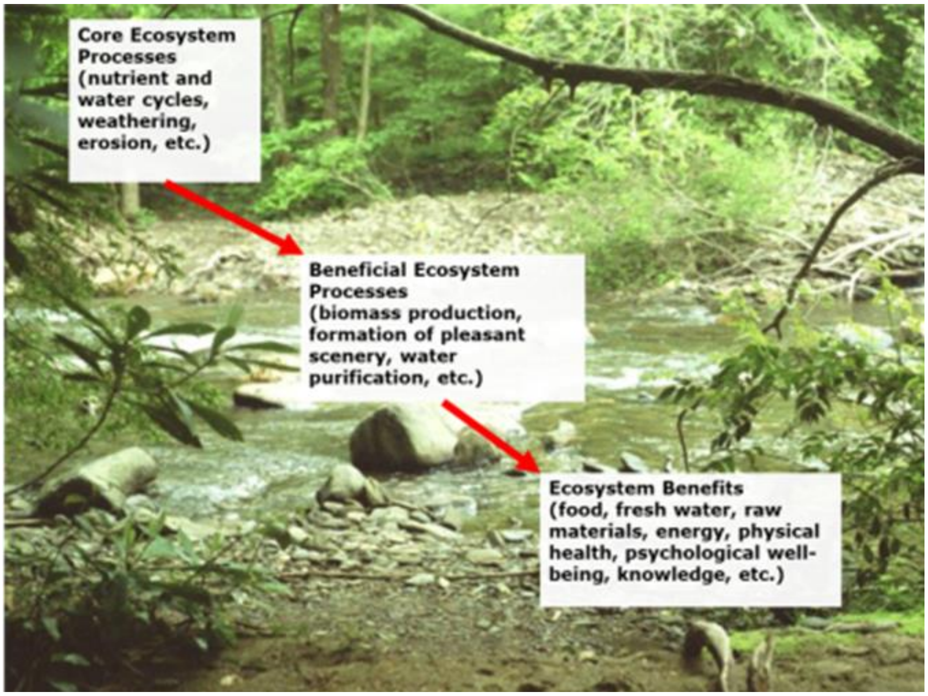

Figure 2: The ecosystem service cascade.

This definition provides a good starting point, and Balmford, et al. (2010, 2013) present a framework for thinking about ecosystem services that adds clarity by "disaggregating ecosystem services into three interlinking sets, which differ in their proximity to human well-being: core ecosystem processes, beneficial ecosystem processes, and ecosystem benefits (p. 164)." This chain of relationships, illustrated in Figure 2, from core processes to beneficial processes to human benefits, is implicit in Johnson's definition.

By separating the sets, these authors provide terms to clarify when we are talking about ecological endpoints (or components of nature) versus economic endpoints (human enjoyment/consumption/use). It is the latter linkage from beneficial processes to benefits themselves that provides the basis for identifying the economic/human connections most relevant to national forest planning.

It is worth putting a bit more complexity into our mental picture of ecosystem services. Figure 3 shows the same cascade in the form of a "concept map" of propositions, such as "Core & beneficial ecosystem processes combine with Human appreciation of natural systems to define Ecosystem benefits" or "Ecosystem benefits, when consumed or realized affect human well-being, which informs human appreciation of natural systems." (Follow the arrows to read other propositions. In this concept map, solid lines represent tangible, biophysical, or economic connections and dashed lines represent information flows.)

In addition to the relationships depicted in Figure 2, the concept map illustrates what comes next: the consumption or realization of ecosystem services which both enhances human well-being and affects ecosystem processes.

For example, human well-being informs both our appreciation of natural systems (drinking a glass of water makes us appreciate clean water) and our actions to conserve or enhance the underlying conditions (dubbed natural capital) that keep ecosystem processes going (Farley, 2012). Those actions may include land and resource management planning or the creation of market incentives or other initiatives. The purpose of such actions would be to support core and beneficial ecosystem processes directly, or to mitigate the effect of stressors that damage them those processes.

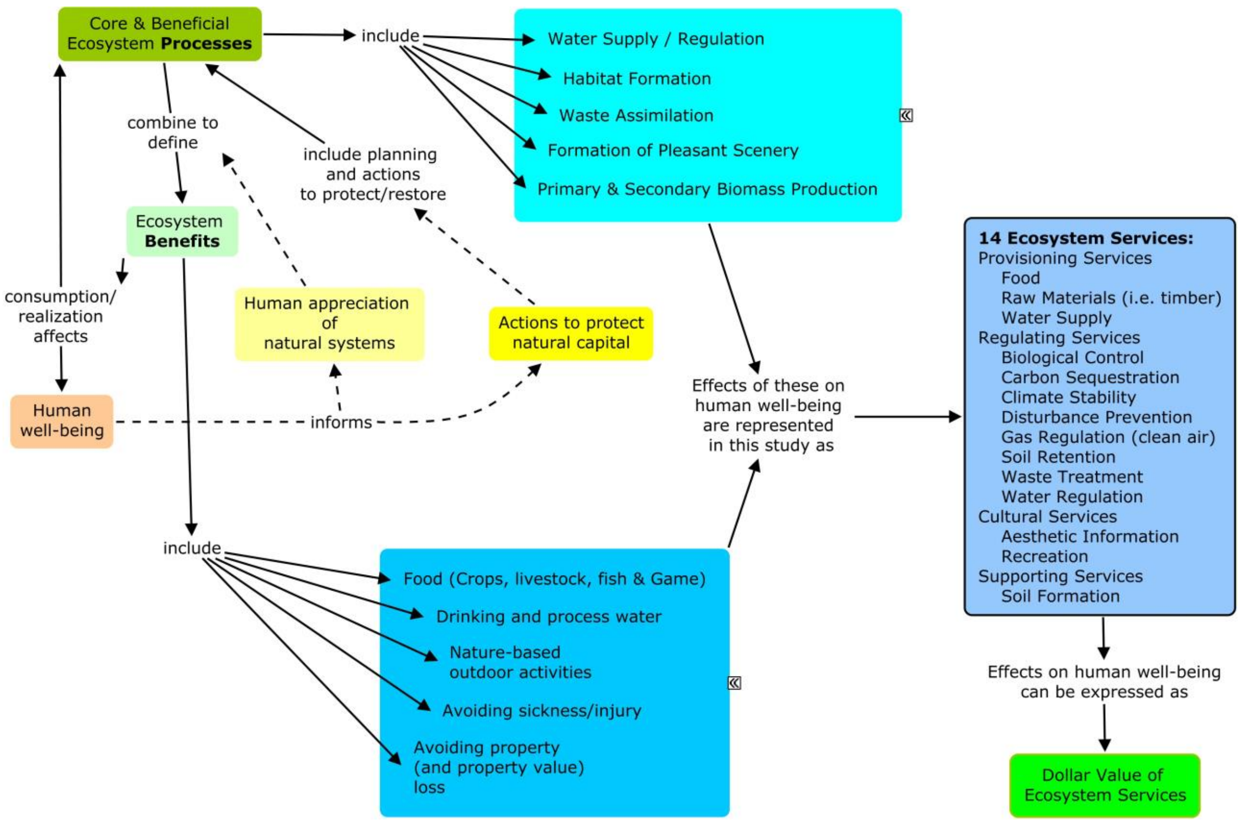

Figure 3: Ecosystem services, with feedback loops

It is worth adding this complexity to our mental map of ecosystem services for two reasons. One is that Figure 2, which is typical of most diagrams intended to illustrate the ecosystems services concept, leaves out important feedback loops from the consumption of ecosystem services back to the condition of ecosystems that make further consumption possible. As much as we might like ecosystem services to be never-ending fountains of human happiness, they are unavoidably parts of complex systems that we can all too easily damage. We have to be willing to "give something back" to sustain those services.

The second reason is to place national forest plans and subsequent management actions squarely within this complex system. They should be understood as necessary elements in the positive feedback loop from ecosystem benefits, through human actions that protect or enhance ecosystem processes, which in turn improve the chances for ecosystem benefits to continue.

Figure 3 also depicts how this system is interpreted and used in this study. The section on "Ecosystem Service Valuation," below, provides details, but in general the study includes estimates of the monetary value of 13 ecosystem services grouped according to the categories provided in the planning rule (USDA Forest Service, 2012). Ideally, one might prefer to consider the many ways in which ecosystem processes individually contribute to ecosystem benefits. Balmford et al. (2010) describes a matrix of process-benefit interactions, and Phillips (2013) provides a tool for qualitative assessment of those interactions as a starting point for planning efforts and/or quantification and monetization of each interaction. There are, however, more than 300 such interactions in the Balmford/Phillips models but comparatively few interactions for which specific quantitative estimates of value exist. By ignoring that additional complexity or detail and focusing instead on more standard ecosystem services for which suitable data are available, we provide a more practical guide for the incorporation of the ecosystem services framework into national forest planning.

ECOSYSTEM SERVICES INCLUDED IN THE STUDY

Studies focused on valuing natural capital often include as many as twenty or more different ecosystem service categories (See, for example, Costanza et al. (1997), Esposito et al. (2011), Swedeen and Pittman (2007), and Flores et al. (2013).) Such studies often apply the value of each ecosystem service to the entire study area while using expert opinion or public input to adjust the productivity of each type of land use (forest, cropland, urban, etc.) for producing each ecosystem service. Our approach here is similar in that we do employ productivity adjustments. (See "Ecosystem Services Valuation" below.)

Our approach is also more data-driven or data-dependent, however, and this limits the range of ecosystem services for which we estimate values. We consider only those services for which we have information from previous studies that connect specific land uses to specific ecosystem services and those which we deem appropriate for use in a study of this particular region. Thus, while we can make such a connection between recreational value and several land uses, including water, urban open space and forests, we cannot make the connection to barren land (think rock climbing), pasture lands, or the more developed portions of the urban landscape. This does not mean, of course, that those other areas do not have value for recreation. It simply means that our estimates of the value of covered ecosystem services (see Table 1, below) will be conservative. It also means that some of the ecosystem services one finds in other studies (e.g., pollination, ornamental resources, science & education, to name a few), are not covered at all.

This point cannot be overemphasized: the fact that suitable information on ecosystem service value is not available for some combinations of land use and ecosystem service does NOT imply that those values are zero. They are simply not included in this study out of an abundance of caution regarding over-estimation of aggregate ecosystem service value.

ECOSYSTEM SERVICE BENEFIT ESTIMATION

Economists have developed widely used methods to estimate the dollar value of ecosystem services and/or natural capital. The most widely known example was a study by Costanza et al. (1997) that valued the natural capital of the entire world. That paper and many others since employ the "benefits transfer method" or "BTM" to establish a value for the ecosystem services produced or harbored from a particular place. According to the OECD, BTM is "the bedrock of practical policy analysis," particularly in cases such as this when collecting new primary data is not feasible (OECD, 2006).

As the name implies, BTM takes a benefit estimate already calculated for one set of circumstances (a "study area") and transfers that benefit to another set of reasonably similar circumstances (the "policy area"). (In this case, the policy areas is the Pisgah-Nantahala National Forest Region.) As Batker et al. (2010) put it, the method is very much like a real estate appraiser using comparable properties to estimate the market value of the subject property. It is also very much like using an existing or established market or regulated price, such as the price of a gallon of water, to estimate the value of some number of gallons of water to supplied in some period of time. The key is to select "comps" that match the circumstances of the subject area as closely as possible.

Typically, comps are drawn from source studies that estimate the value of various ecosystem services from similar land cover types (sometimes called "biomes"). Also typically, it is benefit per unit area (acres in our case) in the study area that is transferred to comparable acreage in the policy area. So, for example, if data for the study area includes the value of forest land for recreation, one might apply per-acre values from the study area's forest to the number of acres of forestland in the policy area. Furthermore, it is important to use source studies that are from regions with underlying economic, social, and other conditions that are similar to the policy area. Due to differences in wealth between countries and regions, for example, observed market prices and expressions of willingness to pay (as a substitute for market prices when no market good is involved) can vary widely.

Careful as one may be to select appropriate comps, estimates coming from the benefits transfer method must be understood to be an approximation of the true value of ecosystem services in the policy area or subject region. It is not the same as measuring the biophysical outputs of every acre in the policy area and then determining the willingness to pay for each of those outputs[1]. The latter would be prohibitively expensive, given that our 18-county policy area consists of 4.7 million acres. (See Figure 6 for a map of the policy area.) Moreover, even measuring the biophysical outputs would still entail a sort of benefit transfer in that one would apply an observed or estimated value-per-unit for some sample of outputs to those outputs estimated for the policy area.

The estimates of ecosystem service value presented below are certainly different from what the actual values would be if we could observe and measure them directly. However, we submit that the model and its resulting estimates are useful at least as a first approximation of the magnitude of those benefits.

[1] This is the "production function" approach to estimating ecosystem service value outlined, for example, in Kareiva et al. (2011)

TABLE 1: ECOSYSTEM SERVICES INCLUDED IN VALUATION[A]

Provisioning Services
Food Production: The harvest of agricultural produce, including crops, livestock, and livestock by-products; the food value of hunting, fishing, etc.; and the value of wild-caught and aquaculture-produced fish. **Associated land uses[B]:** Cropland, Pasture/Forage, Wetland
Raw Materials: Fuel, fiber, fertilizer, minerals and energy **Associated land uses[B]:** Forest
Water Supply: Filtering, retention, storage, and delivery of fresh water—both quality and quantity—for drinking, irrigation, industrial processes, hydroelectric generation, and other uses. **Associated land uses[B]:** Wetland
Regulating Services
Biological Control: Inter- and intra-specific interactions resulting in reduced abundance of species that are pests, vectors of disease, or invasive in a particular ecosystem. **Associated land uses[B]:** Cropland, Forest
Carbon Sequestration: Storing atmospheric carbon in biomass and soil as an aid to the mitigation of climate change. **Associated land uses[B]:** Cropland, Forest, Wetland
Climate Stability: Modulation of regional/local climate (temperature, humidity, rainfall, etc.). Does not include contribution to global climate change mitigation. **Associated land uses[B]:** Urban Open Space, Wetland
Disturbance Prevention: Preventing and mitigating impacts on human life, health and property by attenuating the force of winds, extreme weather events, floods, etc. **Associated land uses[B]:** Urban Open Space, Wetland
Gas Regulation: Removing impurities from the air to provide healthy, breathable air for people. **Associated land uses[B]:** Urban Open Space, Wetland
Soil Retention: Retaining arable land, stabilizing slopes, shorelines, riverbanks, etc. **Associated land uses[B]:** Forest
Waste Treatment: Improving soil and water quality through the breakdown and/or immobilization of pollution. **Associated land uses[B]:** Pasture/Forage Grassland, Forest, Wetland
Water Regulation: Modulation by land cover of the timing of runoff and river discharge, resulting in less severe drought, flooding, and other consequences of too much or too little water available at the wrong time or place. **Associated land uses[B]:** Urban Open Space, Urban Other
Cultural Services
Aesthetic Value: The role that beautiful, healthy natural areas play in attracting people to live, work, and recreate in a region. **Associated land uses[B]:** Urban Open Space, Pasture/Forage, Grassland, Forest, Cropland
Recreation: The availability of a variety of safe and pleasant landscapes—such as clean water and healthy shorelines—that encourage ecotourism, outdoor sports, fishing, wildlife watching, etc. **Associated land uses[B]:** Water, Urban Open Space, Cropland, Shrub/Scrub, Forest

A. (Balmford et al., 2010, 2013; R Costanza et al., 1997; Reid et al., 2005)

B. “Associated Land Uses” are limited to those for which per-unit-area values are available in this study.

With that caveat in mind, we develop and apply an enhanced version of the benefits transfer method that both uses comparable sources of per-acre ecosystem service values and adjusts the estimates to account for differences in per-acre productivity in the subject area.

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The estimates of ecosystem service value presented below are certainly different from what the actual values would be if we could observe and measure them directly. However, we submit that the model and its resulting estimates are useful as a first approximation of the magnitude of those benefits.

So, with that caveat, we develop and apply an enhanced version of the benefits transfer method that both uses comparable sources of per-acre ecosystem service values and adjusts the estimates to account for differences in per-acre productivity in the subject area.

Overview of Methods

Following Esposito et al. (2011), Esposito (2009), and Phillips and McGee (2014), we employ a four-step process to evaluate ecosystem service value of the Pisgah-Nantahala National Forest region (hereinafter the "PNNF Region"). These steps are described in greater detail below, but in summary, they are:

1. Assign land and water in the PNNF Region to one of 10 land uses based on remotely sensed (satellite) data in the National Land Cover Dataset (NLCD) (Fry et al., 2011).

[2] This is the "production function" approach to estimating ecosystem service value outlined, for example, in Kareiva et al. (2011)

2. For the purpose of estimating "raw material" (i.e., timber) value, subtract from total forest acreage those areas unavailable for timber harvest, namely forest land in Wilderness areas and in the Great Smoky Mountain National Park. Since timber harvest does not occur on these acres, they do not have timber value.

   In the concept map (Figure 4) below, steps 1 and 2 are illustrated by the three purple boxes at the left.

3. Establish an index of ecosystem health/productivity for each location in the PNNF Region and use this proxy to discount or adjust acreage in each land use. The proxy for ecosystem health is derived from an existing index of "wildness" that reflects the relative lack of pollution and other human disturbance for each 1km-by-1km portion of the landscape. By multiplying this percentage times the number of acres in each land use within that square, we obtain "productivity-adjusted land area," or the base of land available for producing ecosystem services.

   In the concept map, this step appears as the rose and blue boxes.

4. Calculate aggregate value of 13 ecosystem services by multiplying productivity-adjusted land area (acres) times dollars-per-acre-per-year for those services from appropriate "study sites." Land area and per-acre values are matched by land use.

   The yellow and green boxes in Figure 4 represent this final step.

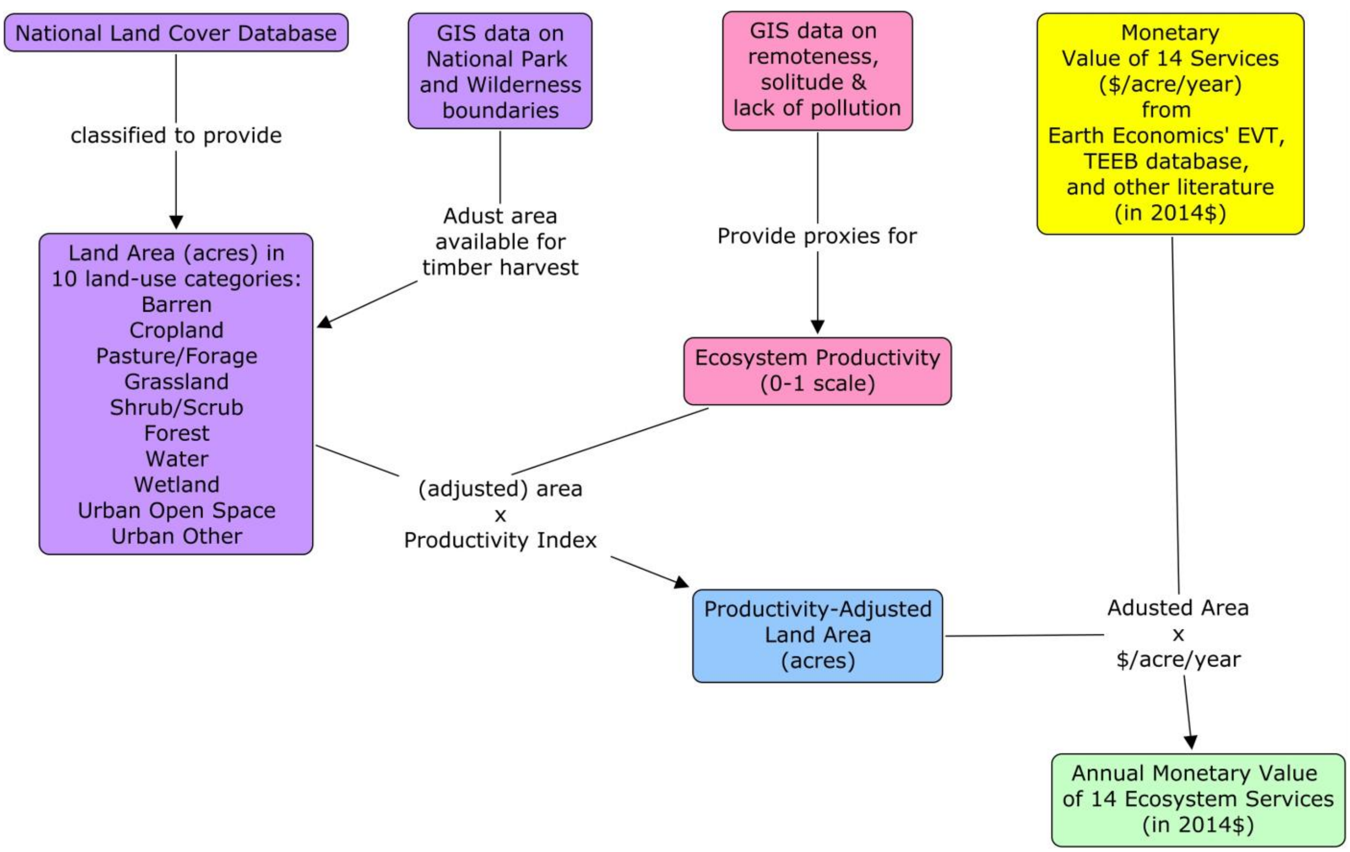

Figure 4: Concept map of method for estimating the monetary value of ecosystem services in the Pisgah-Nantahala National Forest Region.

Step 1: Assign Land to Ecosystem Types, or Land Uses

As indicated in the summary above, the first step in the process is to determine the area in the ten land use groups in the PNNF Region. This determination is made using remotely sensed data from the National Land Cover Database (NLCD) (Fry et al., 2011). These satellite data provide an image of land in one of up to 21 land cover types at the 30-meter level of resolution. Fifteen of these land cover types are present in the PNNF Region (see Figure 5).

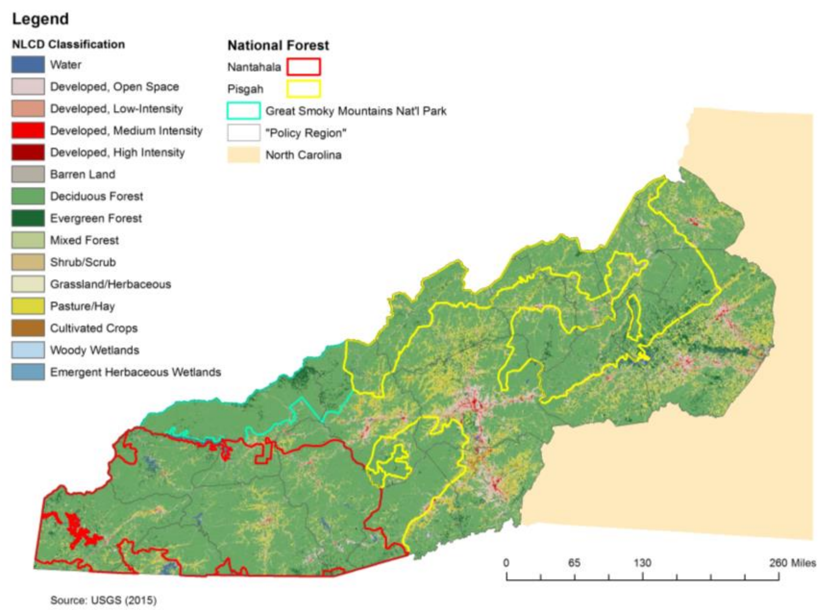

Figure 5: NLCD land classification in the Pisgah-Nantahala National Forest Region

Looking forward to the final step, we will use land use categories to match per-acre ecosystem value estimates from study sites to this policy site (i.e., the PNNF Region). Unfortunately, there are not value estimates for all of the detailed land use categories present in the region. We therefore simplify the NLCD classification by combining a number of classifications into larger categories. Specifically, Low-, Medium-, and High-intensity development are grouped as "Urban Other," and Deciduous, Evergreen and Mixed Forest are grouped as "Forest."

In addition, we add land in the NLCD category of "woody wetlands" to the "Forest" category for two reasons. The first is that, left to their devices, such wetlands would normally become forest in the PNNF Region. Second, wetlands have some of the highest per-acre values for several ecosystem services. So, to avoid over-estimating the ecosystem services contribution of "woody wetlands," we instead count them as "forest."

In the end, we have the 10 land use categories listed in Table 2, at left.

Table 2: Land Use Classification.

NLCD Land Cover Class and Description		Reclassified Land use
11	Open Water	Open Water
21	*Developed, Open Space*	Urban Open
22	Developed, Low Intensity	Urban Other
23	Developed, Medium Intensity	Urban Other
24	Developed, High Intensity	Urban Other
31	Barren Land	Barren Land
41	*Deciduous Forest*	*Forest*
42	*Evergreen Forest*	*Forest*
43	*Mixed Forest*	*Forest*
52	Shrub/Scrub	Shrub/Scrub
71	Grassland/Herbaceous	Grassland
81	Pasture/Hay	Pasture/Forage
82	Cultivated Crops	Cropland
90	*Woody Wetlands*	*Forest*
95	Emergent Herbaceous Wetlands	Wetland

Step 2: Adjust Forest Acreage for Estimation of Raw Material Value

Because forested areas in the Great Smoky Mountains National Park and in designated Wilderness in the Pisgah and Nantahala National Forests are not available for timber harvest, we subtract those acres from total forest acres for the purpose of estimating "raw material" value. (Raw material value, in this study, consists entirely of timber value.)

Step 3: Ecosystem Services Productivity

Estimates of the value of natural capital, including those developed here, typically rely on a per-unit-area values from study sites for the various services provided. These estimates may reflect ideal or pristine conditions and not the actual health of the policy area, where habitats and the associated ecosystem services productivity may be degraded by human activities. Consequently, our approach involves discounting ecosystem service values using a proxy for ecosystem service productivity or ecosystem health.

Our proxy is a variant of the "index of wildness" developed by Aplet, Wilbert, and Thomson (2000). (For a detailed description of the conceptual basis for the wildness index and its component measures, please see that study as well as Aplet (1999) and Aplet, Wilbert, and Morton (2005).) Briefly, however, and for the purposes of this study, we use data supplied by Wilbert (2014) for the following landscape attributes:

1. Solitude, measured by the population density of census block groups.
2. Remoteness, measured by the distance of 210-meter grid cell to the nearest primary, secondary, or tertiary road.
3. Lack of pollution, measured by a combination of the darkness of the night sky, degree of stream impairment, and county-level cancer risk.

Each of these indicators is then turned into an index, with one being the most impacted and five being the least impacted. Summing these across the three indicators, the least healthy areas would score a three out of a possible 15, or 20%, and the healthiest areas would score a 15 or 100%. The average of this health proxy indicator was calculated for habitats in each of the upland segments. Figure 6 displays this index for the PNNF Region. As would be expected from the measures used, areas closest to cities tend to be the least healthy (indicated by the lightest green in the map), while areas farther away from large concentrations of people and built infrastructure tend to be more healthy.

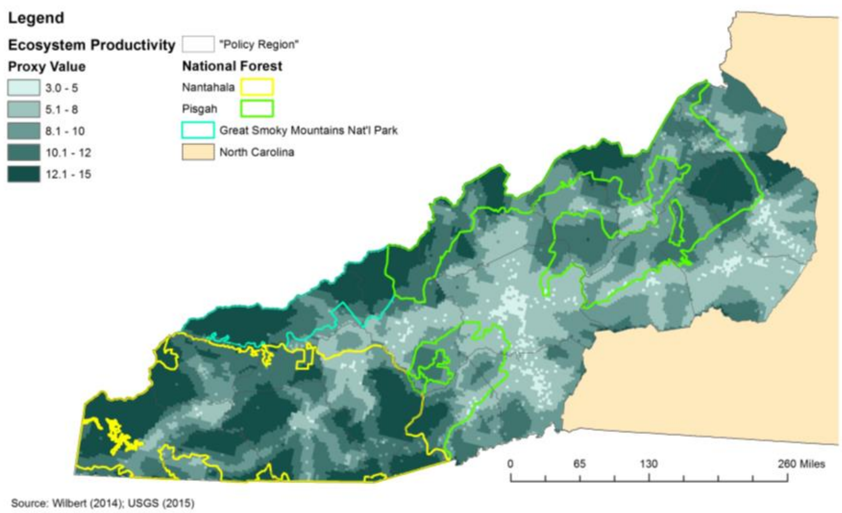

Figure 6: Land Health in the Pisgah-Nantahala National Forest Region

We believe that this index, which indicates the degree to which a given point on the map is affected by human activity, supplies a fair proxy for the relative ability of those places to produce ecosystem services. Note, however, that the conversion of the ordinal wildness indicators into this continuous variable does mean that the lowest possible health index value is actually 0.200, rather than zero. We have chosen to use this truncated distribution and live with the fact that we know that for some areas, this measure of health may be too forgiving.

We next overlay or combine the productivity index data with the land use data from Step 1 to assign the appropriate productivity index value to each land use cell. If the index value is multiplied times the number of acres represented by the cell (which happens to be approximately 0.2224 acres) we can think of the result as the number of acres that *could* produce the full complement of ecosystem services one would expect from the land use *discounted* by the health of the cell.

Thus, in the concept map above (Figure 5), we label this result "Productivity-Adjusted Land Area."

A hypothetical example: Suppose an acre of forest land could, at peak productivity or in pristine condition, produce $100 worth of carbon sequestration each year. Suppose also that one particular acre of forestland is close to a highway in a more densely populated area that has significant pollution. If the cumulative effect of these is that, rather than being pristine (and operating at 100% capacity), our particular acre is only 75% healthy, then we could treat the one acre of less-than-perfect forestland as if it were 0.75 acres of perfectly healthy forestland. We would then expect to receive only $75/year in carbon sequestration value from this particular plot of forest.

In the spirit of the Forest Services "All Lands" approach to planning, our primary interest is in performing these calculations for the entire 18-county Pisgah-Nantahala National Forest Region. We expect, however, that there will be value in also knowing how much ecosystem service value originates from the National Forests themselves. We therefore provide acreage, health, and ultimately ecosystem service value estimates for both the entire PNNF Region and for just the two National Forests.[3]

Table 4 provides total acreage and average productivity for the entire PNNF Region and for the National Forests alone. Not surprisingly, given the way the productivity index is constructed, the average in nearly every land use category is about 60%. This means that no one land use is exceptionally more or less healthy than the others in this region. However, it is interesting, though also not surprising, average health is somewhat higher than for land within the national forests' proclamation boundaries. National forests do tend to be freer of pollution, less heavily roaded and farther from high-population-density areas, and all of those factors are associated, in this study, with higher ecosystem service productivity.

Table 3: Acreage and Productivity, by Land Use for the Pisgah-Nantahala National Forest Region

	Full Region		National Forest Lands Only	
Land use	Acreage	Average Productivity	Acreage	Average Health
Barren	6,008	60.0%	2,689	63.3%
Cropland	20,181	60.0%	4,173	63.3%
Pasture/Forage	413,031	60.0%	114,708	60.0%
Grassland	53,636	60.0%	16,486	63.3%
Shrub/Scrub	57,396	60.0%	24,811	63.3%
Forest	3,800,095	60.0%	2,156,659	60.0%
Water	40,119	60.0%	12,399	63.3%
Wetland	22	55.8%	-	n/a%
Urban Open Space	316,141	60.0%	108,171	60.0%
Urban Other	71,274	60.0%	11,225	63.3%
Total	**4,777,901**	**59.7%**	**2,451,322**	**62.5%**

Two of the acreage estimates for land within the national forests may seem odd at first. Namely, one does not expect to find much pasture/forage land and certainly not much cropland within a national forest. However, recall that we are using the proclamation, not the ownership, boundary to define whether a given area is inside or outside the Pisgah or Nantahala National Forest. There evidently are several agriculture operations within the proclamation boundary. In addition, it is quite possible that what shows up as pasture/forage land on the satellite imagery might in some cases be better classified as grassland. A meadow on a bald, for example, may look as much like pasture to a satellite.

Step 4: Translation to Monetary Values

Finally, we reach the fourth step in which ecosystem service productivity per unit of land or water is converted to a value (i.e., dollars per year). Data for these calculations come from a custom dataset drawn from the Earth Economics' Ecosystem Valuation Toolkit (Briceno & Kochmer, 2014). The toolkit includes an extensive database of ecosystem service valuation studies from which Earth Economics has extracted those studies most applicable to the Southern Appalachians. These

[3] Note that we are using the *proclamation* boundaries of the two national forests to define which lands are counted as in the Pisgah or Nantahala National forests. Using the *ownership* boundaries, naturally, would result in smaller acreage and ecosystem service estimates.

studies provide estimates of ecosystem service benefits for each land use expressed as dollars per acre per year. From the more than 2,000 studies included in the database, estimates selected are those that are the best fit for the PNNF Region either because the underlying studies were done in the Southern Appalachians or a similar landscape, or because they come from studies of ecosystem services that are similar to those produced in the PNNF Region (Briceno & Kochmer, 2014). Not all possible combinations of land use and ecosystem service were covered in the database, however, so to fill some of the gaps, we turned to other tools, including the "The Economics of Ecosystems and Biodiversity" (TEEB) project and, for food value, the rental value of crop and pasture land in the region (USDA-NASS, 2014; Van der Ploeg, Wang, Gebre Weldmichael, & De Groot, 2010).

Several studies report a range of dollar-per-acre ecosystem service values, and for our estimates we report both a low and a high estimate based on the bottom and top end of the range, when available. For combinations of land use and ecosystem service for which multiple studies are available, we use the average of the values reported from each study. (Where a range is reported, we take the average of the low estimates as our "low" figure and the average of the high estimates as hour "high" figure.)

In the end, we have 50 studies or other data sources that yielded per-acre estimates for 33 combinations of land use and ecosystem service. (See Appendix A to this report for a full list of the values and sources that yielded these parameters.) This is still fairly sparse coverage, given that there are 140 possible combinations of the 10 land uses and 14 services. We therefore know that our aggregate estimates will be lower than they would be if dollar-per-acre values for all 14 services were available to transfer to each of the 10 land use categories in the PNNF Region. We can either live with that known underestimation, or we can assign per-acre values from a study of one land-use-and-service combination to other combinations. Doing so would introduce unknown over- or perhaps under-estimation of aggregate values. We prefer to take the first course, know that our estimates are low/conservative, and bear that in mind when considering policy or management actions.

Putting It All Together

With the steps above complete, we can now estimate the annual ecosystem service value for the region according the general formula:

$$\text{ESV} = \sum_{i,j}[(Acres_j) \times (\text{Productivity}) \times (\$/acre/year)_{i,j}]$$

Where:

Acres$_j$	*the number of acres in land use (j)*
Productivity	*is the ecosystem service productivity proxy assigned to each acre*
(\$/acre/year)$_{i,j}$	*is the dollar value of each ecosystem service (i) provided from each land use (j) each year. These values are drawn from the Ecosystem Valuation Toolkit and other sources listed in the Appendix.*

ESTIMATES OF ECOSYSTEM SERVICE VALUE

For the entire 18-county Pisgah-Nantahala National Forest Region, our estimate of the total value of all ecosystem services ranges from $14.0 to 50.1 billion per year (see Table 4, below). The vast majority of this value originates on forested lands, which tracks with the fact that forestland is the dominant land use in the region. Urban open space, water and land devoted to pasture/forage are the next largest contributors to ecosystem service value.

The Pisgah and Nantahala National Forests contribute disproportionately to this total ecosystem service value. Together they represent just over 50% of the land area[4], but they contribute 59% of the ecosystem service value. This occurs due to the higher concentration of forest land within the proclamation boundaries and because forestland generally has higher per-acre ecosystem service value than other land uses. It also had to do with the higher productivity noted above.

Table 4: Total Ecosystem Service Value, by Land Use
(All estimates in 2014 dollars)

	Full Region		National Forest Lands Only	
Land use	**Total ESV (Low Estimate)**	**Total ESV (High Estimate)**	**Total ESV (Low Estimate)**	**Total ESV (High Estimate)**
Barren	-	-	-	-
Cropland	1,645,499	4,398,219	404,839	1,082,084
Pasture/Forage	29,971,781	33,390,829	9,728,404	10,838,177
Grassland	5,842,198	23,858,418	2,100,320	8,577,303
Shrub/Scrub	145,556	145,556	70,873	70,873
Forest	13,004,163,236	49,525,513,075	7,854,404,971	29,857,776,509
Water	119,137,020	126,724,816	39,606,221	42,128,728
Wetland	179,604	741,157	-	-
Urban Open Space	861,576,488	969,800,211	361,416,487	406,814,473
Urban Other	229,153	229,153	48,378	48,378
Total	**$14,022,890,537**	**$50,684,801,432**	**$8,267,780,491**	**$30,327,336,524**

In Table 5, we divide the same total value among the various ecosystem services, and see that aesthetic information, waste treatment, recreation and raw materials account for much of the total value, whether on the national forests or in the larger landscape. Aesthetic information alone accounts for more than 80% of the ecosystem service value in the region owing, in part, to the fact that there is better coverage of this ecosystem service value than for others, such as water regulation or climate stability. The result is not entirely an artifact of data limitations, however. It is likely that there are more studies of aesthetic value simply because aesthetics are important to citizens and decision-makers and, therefore, it has garnered more research attention.

Even so, interpretation of these results must be tempered by an understanding that there are many combinations of land use and ecosystem services for which we do not have any estimates to transfer to our policy site, the PNNF Region. Adding data sources from additional study sites would certainly increase estimates of total ecosystem service value and change the distribution of the total among individual services.

[4] Here, as throughout the report, we are using the proclamation boundaries to define the geographic extent and acreage of the two national forests. The number of acres in federal ownership is, of course, much smaller, totaling 1.04 million acres or about 22 percent of the study region.

Table 5: Total Ecosystem Service Value, by Ecosystem Service
(All estimates in 2014 dollars)

		Full Region		National Forest Lands Only	
	Ecosystem Service use	Total ESV (Low Estimate)	Total ESV (High Estimate)	Total ESV (Low Estimate)	Total ESV (High Estimate)
Provision-ing	Food	6,372,775	6,372,775	1,989,890	1,989,890
	Raw Materials	383,962,554	383,962,554	250,990,006	250,990,006
	Water Supply	116,694	116,694	-	-
Regulating	Biological Control	40,460,285	42,534,146	24,320,735	24,830,962
	Carbon Sequestration	8,686,973	120,809,894	5,232,091	72,763,198
	Climate Stability	135,211,402	135,269,667	56,718,533	56,718,533
	Disturbance Prevention	54,870,069	104,282,907	23,013,266	43,544,708
	Gas Regulation	19,545,661	19,545,934	8,198,683	8,198,683
	Soil Retention	8,194,065	95,597,420	4,936,757	57,595,504
	Waste Treatment	704,104,698	707,064,367	424,180,748	425,948,666
	Water Regulation	12,969,542	17,260,213	5,392,752	7,192,614
Cultural	Aesthetic Information	11,966,365,162	48,340,135,198	7,169,089,079	29,067,946,178
	Recreation	681,951,441	711,770,447	293,698,462	309,598,091
Sup-porting	Soil Formation	79,217	79,217	19,489	19,489
	Total	**$14,022,890,537**	**$50,684,801,432**	**$8,267,780,491**	**$30,327,336,524**

These Baseline estimates are generally in line with other studies of ecosystem service value (ESV) in other regions. In a recent study of the Chesapeake Bay watershed – an area roughly ten times the size of the PNNF Region – the authors estimated total ESV of $107 billion per year (Phillips & McGee, 2014). That is less than 10 times the low-end value calculated for the PNNF Region, but Phillips and McGee (who used only low-end estimates of per-acre value) considered a more limited list of just eight ecosystem services compared to the 14 counted here.

Another way of gauging whether our estimates of the value of the region's natural systems ring true is to compare them to the size of the region's human economy. For example, total personal income in the PNNF Region was a little over $32 billion (in 2013, adjusted to 2014 dollars), or more than twice the twice the level of our low-end estimates and three fifths the size of our high-end estimates (BEA, 2015; Headwaters Economics, 2015). This makes our results fairly modest, at least by the standard of Costanza et al. (1997), who estimated that the world's ecosystems produce approximately three times as much value each year as do the world's economies.

Our estimates are smaller both because our method entails discounting ecosystem service values according to the land health measure and because we have estimated the value of the subset of ecosystem services for which suitable "comps" could be found. In the global studies, by contrast, the authors considered all services, had far more applicable study sites from which to transfer benefits, and they did not adjust for land health or productivity.

Ecosystem service value can also be explored for smaller geographic units, such as depicted in the maps in Figures 8 through 11. Figure 7, for example, shows the total ecosystem service value at each point (in this an area 30 meters square) on the map. Dark blue indicates the highest value, and red shows the lowest value. Being a function of the land use (land cover), health and per-acre values for different ecosystem services, total ecosystem service value does tend to be higher in forested areas and, among the developed portion of the landscape, in urban open space. Perhaps most saliently for

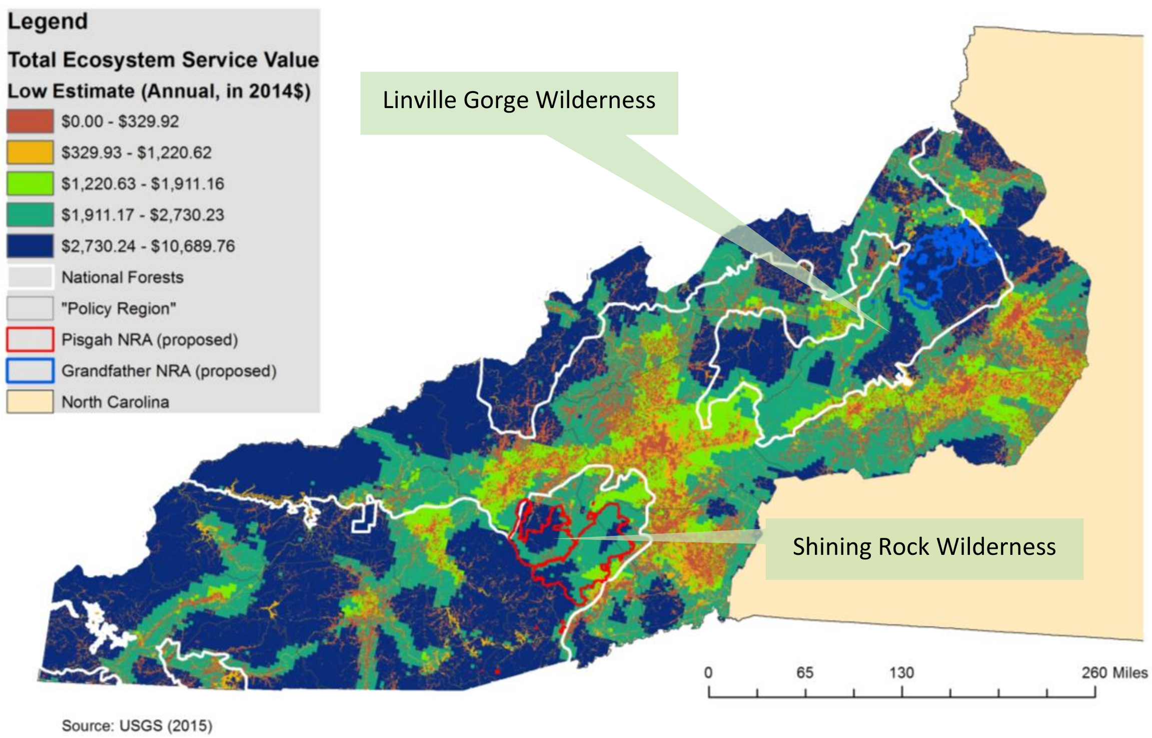

Figure 7: Total Ecosystem Service Value, in 2014$ per 30m cell.

national forest planning, values are also generally higher in and around protected areas such as the Linville Gorge and Shining Rock Wilderness areas.

This mapping shows that areas prioritized for future protection also have relatively high ecosystem service value. The "Mountain Treasures" depicted by cross-hatched areas on the maps have been endorsed by a range of conservation organizations, businesses and others as "the best of what remains on the Nantahala-Pisgah (The Wilderness Society, 2010, p. 3). They are areas with the greatest potential to preserve interior forest habitat, associated biodiversity, and for wilderness experience. In addition, two proposed National Recreation Areas (NRAs) would accomplish many of the same objectives, while emphasizing recreational opportunities such as biking, hiking, fishing, hunting, and birding.

Similar patterns are evident in the maps of Cultural, Regulating and Provisioning services below.

CONCLUSION AND RECOMMENDATIONS

The natural systems of the Pisgah-Nantahala National Forest Region provide diverse ecosystem services to the region's residents and communities and are worth between $14.0 and $50.6 billion dollars per year. Land within the Pisgah and Nantahala National Forests themselves contribute disproportionately to this total, demonstrating not only the value of these public lands, but also the great responsibility that falls to the USDA Forest Service in planning for and exercising sound stewardship of those lands. Due to the spatially explicit methods employed in the present study, we can also see that areas suitable for allocation to more protective management classes (wilderness and/or national recreation area) are already producing high ecosystem services values. It is likely therefore, that such allocation would further the purpose of national forest planning "…to provide people and communities with ecosystem services and multiple uses that provide a range of social, economic and ecological benefits for the present and into the future (26 CFR 219)."

The National Forest Planning Rule provides a solid impetus to assess and ensure the delivery of these ecosystem services. To date, however, the Pisgah-Nantahala planning process has not fully tapped into the potential of ecosystem services to organize its analysis of the economic benefits associated with national forest management. The framework and analysis presented here provides one possible way to delve deeper and provide a more robust consideration of ecosystem services.

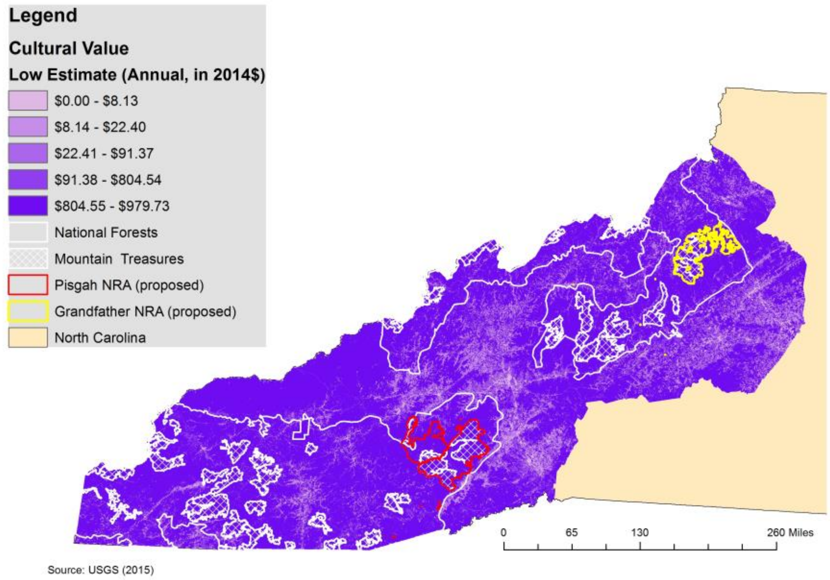

Figure 8: Value of Cultural Services in 2014$ per 30m cell. Included cultural services are aesthetic value and recreation.

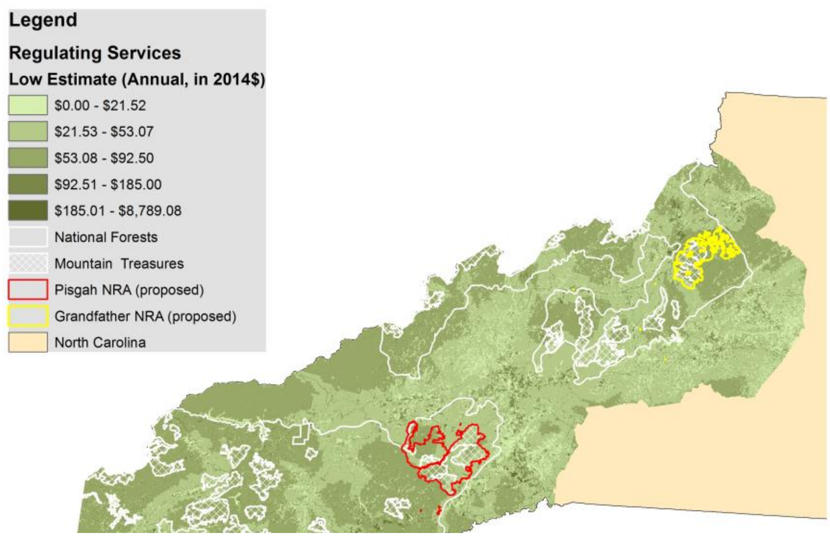

Figure 9: Value of Regulating Services, in 2014$ per 30m cell. Included regulating services are biological control, carbon sequestration, climate stability, disturbance prevention, gas regulation, soil retention, waste treatment and water regulation.

At a minimum we recommend the following as part of a strategy for both early adoption of the Planning Rule's emphasis on ecosystem services and for leadership in using ecosystem services to guide land allocation and management decisions:

- That the Forest Service use a complete and coherent ecosystem services framework to evaluate how various values people have related to the national forests fit into the standard classification of ecosystem services (e.g. into provisioning, regulating, cultural and supporting categories) to reduce confusion in the analysis. It is essential that measures of some of the consequences of ecosystem services (e.g. jobs and income) not be mistaken for ecosystem services themselves.

- That the Forest Service employ Benefits Transfer or other standard methods to provide quantitative estimates for the value of ecosystem services provided by land under its management and, more broadly, "all lands" influenced by the Agency's actions.

- That alternatives for the revised forest plan, including aspects dealing with allocation of National Forest System lands to protective management classifications, be undertaken with an eye toward ensuring the continued flow of valuable ecosystem services for the region.

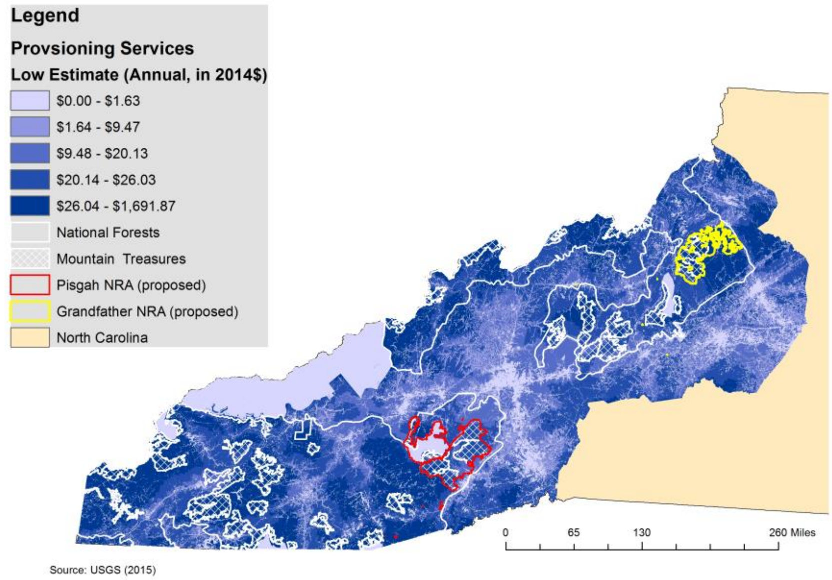

Figure 10: Value of Provisioning Services, in 2014$ per 30m cell. Provisioning services are food and raw material (timber) production, and water supply. Recall that raw materials have been zeroed out for wilderness areas and the Great Smoky Mountain National Park.

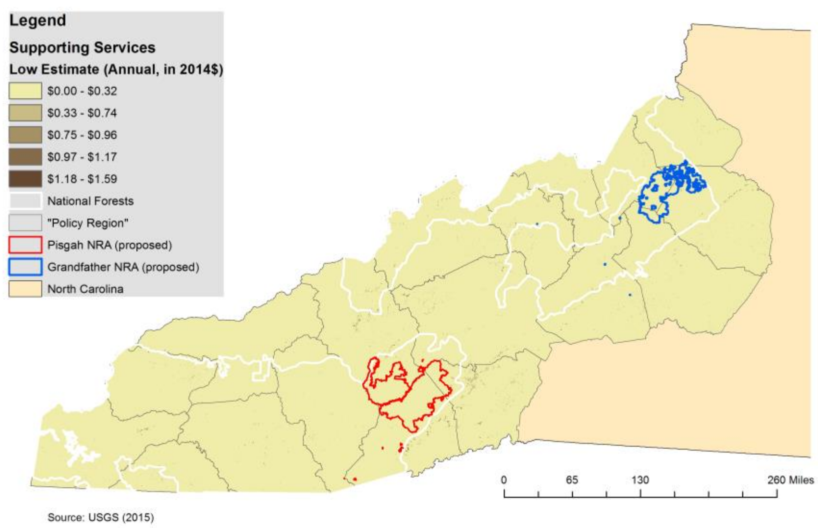

Figure 11: Value of Supporting Services, in 2014$ per 30m cell. The only supporting service for which data were available for this study is soil formation.

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APPENDIX A: ECOSYSTEM SERVICE VALUES

(All values are in 2014 dollars per acre per year)

Land Use	Ecosystem Service	Min $/Acre/Year	Maximum $/Acre/Year	Note	Source[C]
Cropland	Aesthetic Information	34.45	87.81	A	(Bergstrom, Dillman, & Stoll, 1985)
Cropland	Biological Control	14.15	201.68		(Cleveland et al., 2006)
Cropland	Carbon Sequestration	0.41	5.63	A	(Briceno & Kochmer, 2014)
Cropland	Food	90.50	90.50		(USDA-NASS, 2014)
Cropland	Food	2,381.76	2,381.76		(Kauffmann, Gerald, Homsey, Anadrew, McVey, Erin, Mack, Stacey, & Chatterson, Sarah, 2011)
Cropland	Recreation	2.13	4.94	A	(Knoche & Lupi, 2007)
Cropland	Soil Formation	7.16	7.16	A	(Pimentel, 1998)
Forest	Aesthetic Information	4,368.84	17,852.39	A	(Nowak, Crane, & Dyer, 2002)
Forest	Biological Control	14.97	14.97	A	(Brenner Guillermo, 2007)
Forest	Carbon Sequestration	3.23	44.86	A	(Briceno & Kochmer, 2014)
Forest	Raw Materials	159.61	159.61		(Weber, 2007)
Forest	Recreation	36.54	44.78	A	(Prince & Ahmed, 1989)
Forest	Soil Retention	3.04	35.51	A	(Zhou, Al-Kaisi, & Helmers, 2009)
Forest	Waste Treatment	261.54	262.63	A	(Liu, 2006)
Grassland	Aesthetic Information	117.98	280.82	A	(Rosenberger & Waslh, 1997)
Grassland	Aesthetic Information	246.71	1,208.50	A	(Qiu, Prato, & Boehrn, 2006)
Pasture/Forage	Aesthetic Information	100.74	114.75	A	(Ready, Berger, & Blomquist, 1997)

Land Use	Ecosystem Service	Min $/Acre/Year	Maximum $/Acre/Year	Note	Source[C]
Pasture/Forage	Food	22.00	22.00		(USDA-NASS, 2014)
Shrub/Scrub	Recreation	3.89	3.89	A	(Haener & Adamowicz, 2000)
Urban Open Space	Aesthetic Information	990.00	1,301.20	A	(Qiu et al., 2006)
Urban Open Space	Climate Stability	414.15	414.15	B	(Brenner Guillermo, 2007)
Urban Open Space	Climate Stability	1,116.28	1,116.28	A	(G. E. McPherson, 1992)
Urban Open Space	Gas Regulation	31.94	31.94	A	(G. McPherson, Scott, & Simpson, 1998)
Urban Open Space	Gas Regulation	189.28	189.28	A	(G. E. McPherson, 1992)
Urban Open Space	Recreation	2,627.61	2,627.61	B	(Brenner Guillermo, 2007)
Urban Open Space	Water Regulation	8.19	8.19	A	(G. E. McPherson, 1992)
Urban Open Space	Water Regulation	136.02	184.58	A	(The Trust for Public Land, 2010)
Urban Other	Water Regulation	7.48	7.48	B	(Brenner Guillermo, 2007)
Water	Recreation	152.88	899.51	A	(Cordell & Bergstrom, 1993)
Water	Recreation	299.32	430.21	A	(Mullen & Menz, 1985)
Water	Recreation	2,669.01	2,857.41	A	(Burt & Brewer, 1971)
Water	Recreation	13,614.87	13,614.87	A	(Mathews, Homans, & Easter, 2002)
Wetland	Carbon Sequestration	0387	14.04	A	(Briceno & Kochmer, 2014)
Wetland	Climate Stability	61.68	4,785.07	A	(Flores et al., 2013)
Wetland	Gas Regulation	74.29	96.45	A	(Jenkins, Murray, Kramer, & Faulkner, 2010)
Wetland	Raw Materials	49.36	49.36	A	(Everard, Great Britain, & Environment Agency, 2009)

Land Use	Ecosystem Service	Min $/Acre/Year	Maximum $/Acre/Year	Note	Source[C]
Wetland	Recreation	107.55	423.11	A	(Robert Costanza, Farber, & Maxwell, 1989)
Wetland	Recreation	204.69	204.69	A	(Kreutzwiser, 1981)
Wetland	Recreation	638.21	4,136.71	A	(Whitehead, 1990)
Wetland	Recreation	1,024.42	1,024.42	A	(Creel & Loomis, 1992)
Wetland	Waste Treatment	65.95	6,210.84	A	(Breaux, Farber, & Day, 1995)
Wetland	Waste Treatment	542.22	542.22	A	(Jenkins et al., 2010)
Wetland	Waste Treatment	10,707.46	10,707.46	A	(Liu, 2006)
Wetland	Water Regulation	1,271.60	1,271.60		(Weber, 2007)
Wetland	Water Supply	612.83	612.83	A	(Creel & Loomis, 1992)
Wetland	Water Supply	18,307.22	18,307.22	A	(Thibodeau & Ostro, 1981)

Notes:

A. These values were obtained via contract for a custom data pull from Earth Economics Ecosystem Valuation Toolkit in March 2014. Earth Economics selected options from thousands of studies based on applicability to the Southern Appalachians. http://esvaluation.org/.

B. Values selected from the TEEB (The Economics of Ecosystems and Biodiversity) Valuation Database (Van der Ploeg et al., 2010).

C. Full references are included under "Works Cited," above.