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Valuing our National Parks: an ecological economics perspective

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Abstract: The annual budget for the United States National Park Service was roughly three billion dollars in 2016. This is distributed amongst 405 National Parks, 23 national scenic and historic trails, and 60 wild and scenic rivers. Entrance fees and concessions generate millions of dollars in income for the National Park Service; however, this metric fails to account for the total value of the National Parks. In failing to consider the value of the ecosystem services provided by the National Parks we fail to quantify and appreciate the contributions our parks make to society. This oversight allows us to continue to underfund a valuable part of our natural capital and consequently damage our supporting environment, national heritage, monetary economy, and many of our diverse cultures. We explore a simple benefits transfer valuation of the United States national parks using National Land Cover Data from 2011 and ecosystem service values determined by Costanza (et al). This produces an estimate suggesting the parks provide $84 billion / year in ecosystem service value. If the natural infrastructure 'asset' that is our national park system had a budget comparable to a piece of commercial real estate of this value, the annual budget of the National Park Service would be roughly an order of magnitude larger at something closer to $30 billion rather than $3 billion.

Keywords: National Parks; ecosystem service value; natural infrastructure; natural capital

1. Introduction

1.1 Economic and non-economic value of the United States National Parks

More than 275 million people visit "America's best idea" every year [1]. From the swampy Everglades, reminiscent of the age of dinosaurs, to the purple mountains of Rocky Mountain National Park, the National Parks protect our natural wonders. The social impact of our National Parks is manifold; Americans and foreigners alike can immerse themselves in history at our battlefields and National Historic Sites, and leave their cities of origin to find themselves truly in the wild in parks and National Monuments.

The financial economic impact of our parks is significant. Concessioners within the National Parks generate $1.3 billion in revenue every year, and pay $80 million in franchise fees to the federal government [1]. Communities near the National Parks also depend on park visitation to sustain nearly 300,000 local jobs, and contribute $32 billion to the US economy [1]. The influence of the National Parks reaches beyond their physical boundaries. National Park tours contribute to the international travel industry, small towns that are, "on the way" to the parks benefit from the traffic that runs through.

There are many ways to attribute value to the National Park Service. Some traditional approaches are metrics like number of visitors, concessioner profits, and job growth; however, these give insight into only one element of our National Parks' value. Ecosystem services are the benefits we receive by letting nature operate in its natural ways [2]. Examples of ecosystem services include four broad categories: 1) provisioning services (production of food, fiber, and timber), 2) regulating

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services (e.g. water filtration and climate regulation), 3) supporting services (e.g. nutrient cycling) and 4) cultural services (e.g. recreation, aesthetic inspiration, and cultural identity) [3]. Human wellbeing results from the interaction of ecosystem services with human, social, natural, and built capital [4].

The ways that individuals, communities, and their built environments interact with natural capital is how we reap the benefits of ecosystem services [4]. Ecosystem services and natural capital suffer from many market failure properties including the following: they suffer from both positive and negative externalities, they have unclear property rights, many are open access regimes, and they are often public goods [5]. Estimates of the economic value of ecosystem services suggest their value is almost twice as large as the entire global market economy which precludes any policy attempts to internalize the costs of any externalities associated with damaging ecosystem functions and or services [6]. Because of the many market failure qualities of ecosystem services we argue that structuring the ways our built and social environments interact with ecosystem services is not best optimized by free market principles and policies. Making shifts in the arrangements of social, human, built, and natural capital will likely prove to be quite difficult because preliminary studies in South Australia suggest that those trained in the dominant economic paradigm (people employed in finance, management, and business) have significantly lower levels of ecological literacy [7].

Economic valuation of ecosystem services is often perceived as a way to commodify natural capital thus enabling the preservation of neo-classical economic policy for the 'management' of nature. The immense value of ecosystem services relative to the market economy, in addition to their aforementioned market failure properties, suggest that current environmental challenges result from a failure of governance. Market failures are generally recognized to be an appropriate domain of government intervention. Sustainable and desirable stewardship of our environmental endowment (including our national parks) will likely require new institutions utilizing broader holistic policies, using longer time horizons, and associating significantly higher values to ecosystem services than are currently provided by market based assessments.

1.2 Valuation is not commodification

We explore a simple economic valuation of the lands that exist in the National Parks of the United States using a benefits transfer methodology. There are many criticisms of the very idea of placing an economic value on nature that have undoubtedly contributed to the distracting debate on the difference (or lack thereof) between the idea of Ecosystem Services and 'Nature's Contribution to People' [8][9]. One fundamental criticism from the '*you simply underestimated infinity*' school of thought is that any finite estimate of the value of natural capital is an underestimate because the 'consumer surplus' of nature is infinite – or at least 'all that we could possibly pay' - because without natural capital there is no society, no built capital, no human capital and no economy at all. While this is true, infinity is not a useful number to use when making decisions about allocation of resources. Failure to appropriately value natural capital and ecosystem services has resulted in lost ecosystem services due to land degradation (~$6 trillion / year [6]) and land cover change (~$22 Trillion / year [4]). These losses are massive relative to the size of the market economy and suggest that 'business as usual' free market policies will continue to fail and political solutions associated with responsible governance and sound science are desperately needed in order to succeed.

In a period of political, economic, and social uncertainty, the future of our National Parks hangs in the balance. Ecosystem service valuation provides a method of valuing our Natural Parks that can be useful in resource allocation decisions and enhances our appreciation of their value and the benefits we derive from them. The process of ecosystem service valuation should not be confused with the commodification of nature. Many ecosystem services are non-rival meaning a large number of people can enjoy a hiking trail at a National Park without impairing others enjoyment [10]. Although, when Parks are supplied in such a manner as to be frequently congested we cause many problems including: degradation of the parks themselves, impaired experiences of park visitors, and reduced public access to nature that is likely to be controlled by pricing mechanisms which are likely to increase inequality of access to a public resource. Many ecosystem services are also non-excludable; using the National Parks as an example, the benefits of forests filtering air and sequestering carbon extend far beyond the boundaries of the park [10]. Clearly, it is recognized that National Parks are a public good that should be established and maintained by government; however, failure to appreciate the total value of our parks is resulting in an underinvestment in supply of parks and of supporting infrastructure.

The intent of ecosystem service valuation is not to put a “price tag” on these services or suggest they should be commodified. In fact, one purpose of ecosystem service analysis is to show how our wild places produce value that can be thought of 'in dollars' to those who are unable to frame nature conservation as “a moral issue" [11]. Critics who assume that ecosystem service values are expressed in monetary units for the sake of pricing them for commodification are mistaken; while the values could be expressed in terms of time, energy, or land, these units may not be easily understood by a large audience, particularly those in decision-making positions [4]. It is dangerously naïve to promote a moral path (e.g. 'nature is infinitely valuable') as the primary argument for protecting nature. Of course nature has intrinsic value; however, a collective mindset of this nature has not yet developed to influence policymakers sufficiently. In the meantime “*Appeals to people’s wallets*” may enhance the survival of our National Parks [11].

The National Parks are often regarded as natural capital; however, most of the deferred maintenance making up a $12 billion backlog of work weighing down on the National Park Service relates to crumbling infrastructure [11]. This built infrastructure is a poignant example of how our enjoyment of the parks manifests from an interaction of people, infrastructure, and nature (e.g. Human, Social, Built, and Natural Capital). Typically, property management fees range from 30-50% of the gross rental revenue of a property. If the value of ecosystem services provided by the parks were regarded as a component of the true revenue structure of the National Park Service we could justify a much larger operating budget for the NPS. Currently, the National Park Service’s budget is less than 5% of the annual ecosystem service value of the 46 National Parks involved in this study alone. The National Park service is allotted $2.8 billion a year to distribute between 417 sites [1]. After celebrating their Centennial in 2016, the National Park Service recommitted “*to exemplary stewardship and public enjoyment*” [12]. In order to accomplish this, the National Parks will require increased financial support. A benefits transfer analysis of Yellowstone and Grand Teton National Parks found their combined annual ecosystem service valuation to be $1.4 billion / year, meaning two parks return half of the value of what is spent on the entire system every year [13]. Ecosystem service valuation is a tool that may be used to justify increased financial resources for wild spaces, which provide many more benefits to society than meet most politicians’ eyes.

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2. Materials and Methods

Boundary information for the National Parks was taken from the National Park Service's GIS database. The dataset includes all areas the National Park Service (NPS) is responsible for. We focused the scope of the project to only those components of the NPS that were actual National Parks (does not include national monuments, wild and scenic rivers, etc). Additionally, National Parks outside of the 48 contiguous states were excluded. There were ultimately 46 National Parks included in this ecosystem service valuation.

The National Land Cover Database (NLCD 2011) contains land cover information at 30-meter spatial resolution for the United States. The dataset uses a 16-class land cover classification scheme derived from a combination of Landsat and supplementary imagery [14]. The biome types used for the final ecosystem service valuation were taken from Costanza et al.'s framework [4]. The ecosystem service values were estimates based on 17 types of ecosystem services using a simple benefits transfer method. This approach makes simplifying assumptions about spatial dependence, ecosystem function, and transferability of value [15]. Nonetheless, we argue that these estimates of ecosystem service values are likely underestimates and are plausible and defensible as they are based on thousands of existing peer-reviewed ecosystem service valuations that exist in the TEEB database [16].

NLCD raster data was extracted to the National Park boundaries. Land cover types were reclassified to the biome type they most closely fit (Appendix B for the land cover reclassification scheme). The resulting table for the National Parks produced an area estimate for each biome type within each park. Benefits transfer assumes the value of a wetland in Florida is the same as the value of a wetland in Virginia. To calculate total value of the ecosystems of each park we simply multiplied the biome specific value (Appendix B) by the areal extent of that biome in the park and summed across biomes.

3. Results

The areal extent and annual ecosystem service value of each National Park is summarized (Table 1 and Appendix A). The resulting total estimate of the annual value of the ecosystem services of the National Parks is $84,354,182,628 per year. Everglades National Park has the greatest annual ecosystem service value at $42 billion per year. It has the greatest spatial extent of tidal marsh and mangrove biome types, as well as the greatest spatial extent of swamps and floodplains. It is the third largest National Park by area. The National Park with the lowest annual ecosystem service value is Hot Springs National Park in Arkansas. It is also the smallest National Park by area at just 2,200 hectares.

The ten National Parks with the lowest ecosystem service valuations have a few traits in common. Firstly, they have very little water compared to parks with higher ecosystem service values. They also have very little marsh or swamp land cover. These three biome types provide higher value ecosystem services than others. The 10 parks with the lowest ecosystem service valuations are in arid parts of the country. The three National Parks with the highest annual ecosystem service values are Everglades, Yellowstone, and Death Valley, respectively. They are also the three largest parks by area. Excluding Everglades National Park, the average annual ecosystem service value for a park is $935 million per year, and the average area is 158,595 hectares.

Table 1. The area and annual ecosystem service values of the National Parks in the conterminous United States.

Park Name	Park Area (hc)	Total ESV (2007$/hc/yr)
Acadia	15,699	323,835,363
Arches	30,942	174,533,761
Badlands	98,517	185,207,966
Big Bend	328,701	1,520,197,202
Biscayne	67,875	1,547,824,712
Black Canyon of the Gunnison	12,689	50,157,887
Bryce Canyon	14,564	52,106,649
Canyonlands	135,541	869,372,685
Capitol Reef	98,788	312,867,063
Carlsbad Caverns	18,937	77,754,322
Channel Islands	99,132	818,680,458
Congaree	9,815	1,759,318,009
Crater Lake	73,566	314,913,521
Cuyahoga Valley	13,519	222,245,480
Death Valley	1,376,357	5,506,406,147
Dry Tortugas	25,081	338,238,617
Everglades	622,662	42,279,172,811
Glacier	407,920	1,552,893,238
Grand Canyon	488,719	1,905,101,696
Grand Teton	125,410	1,157,082,094
Great Basin	31,239	112,555,828
Great Sand Dunes	32,745	202,162,116
Great Smoky Mountains	209,826	838,033,309
Guadalupe Mountains	35,566	138,950,941
Hot Springs	2,214	8,852,135
Isle Royale	222,438	4,398,031,263
Joshua Tree	321,049	1,253,450,333
Kings Canyon	185,839	493,947,252
Lassen Volcanic	43,425	169,635,273
Mammoth Cave	20,777	161,522,833
Mesa Verde	21,723	101,593,004
Mount Rainier	95,197	453,652,629
North Cascades	202,767	743,555,127
Olympic	369,955	2,328,065,002
Petrified Forest	90,301	384,863,702
Redwood	46,799	256,456,563

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Rocky Mountain	108,021	555,929,172
Saguaro	37,819	155,575,550
Sequoia	164,710	497,360,250
Shenandoah	78,217	303,000,835
Theodore Roosevelt	28,484	273,624,773
Voyageurs	82,779	2,648,707,339
Wind Cave	11,462	47,226,823
Yellowstone	890,092	5,601,892,458
Yosemite	301,643	1,046,067,701
Zion	59,928	211,560,737
Totals	7,759,448	**84,354,182,628**

Grasslands and forest are dominant biomes in terms of areal extent of the National Parks (Figure 1). Grass/Rangeland is the most prevalent biome type in the National Parks, while cropland was the least. The land cover classification scheme used in this analysis is given in Appendix B. “Desert”, “Tundra’, and “Ice/Rock” are the only three biome types with an ecosystem service value of $0. This is merely a reflection of lack of data in the TEEB database rather than a reflection of low value for those biomes. Clearly Desert, Tundra, and Ice/Rock perform valuable ecosystem services for which we, as of yet, lack a substantial number of peer-reviewed assessments. This is another reason we can regard our estimates as conservative if not low. Forest is the second most prevalent biome type, and has an ecosystem service value per hectare of $3,800 per year. Water is the third most prevalent biome type, and has the third highest annual ecosystem service value of the biomes considered in this study at $12,512 per year. The two most valuable biome types in terms of dollar value of ecosystem services provided do not have substantial spatial extents: Tidal Marsh/ Mangroves and Swamp/ Floodplains.

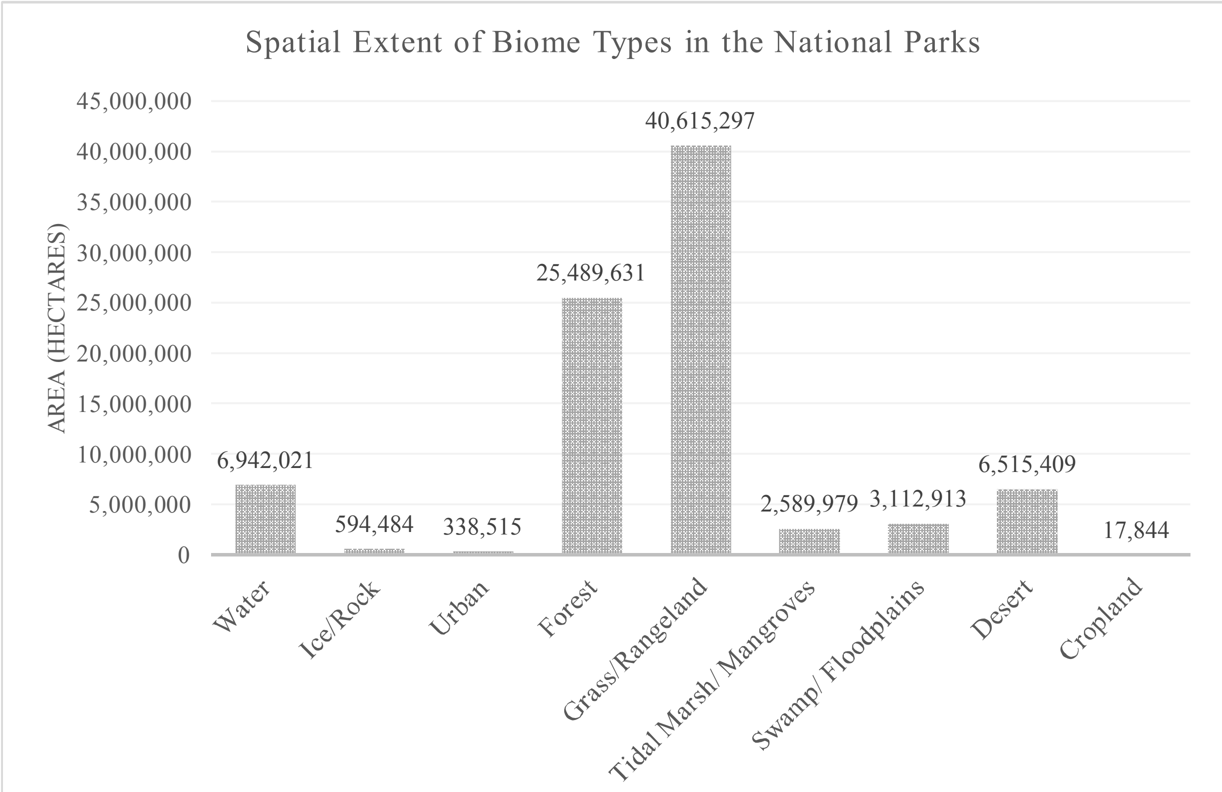

Figure 1: The spatial extent of each biome type in the National Parks in the conterminous United States

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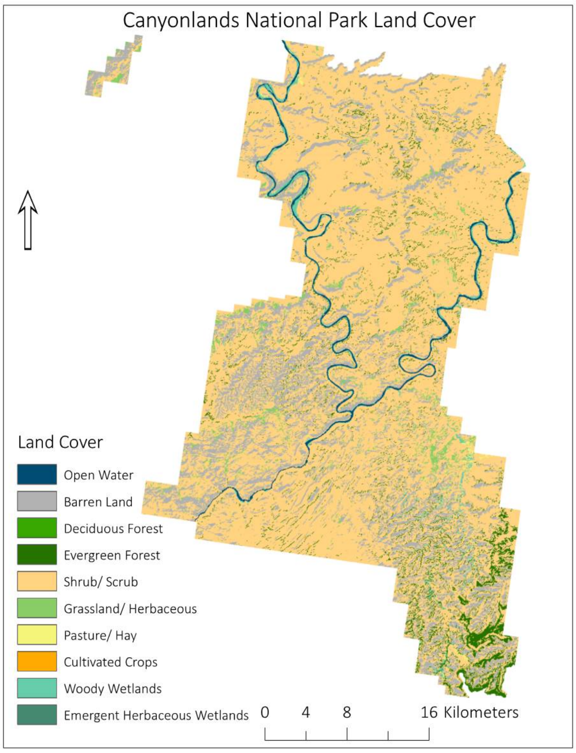
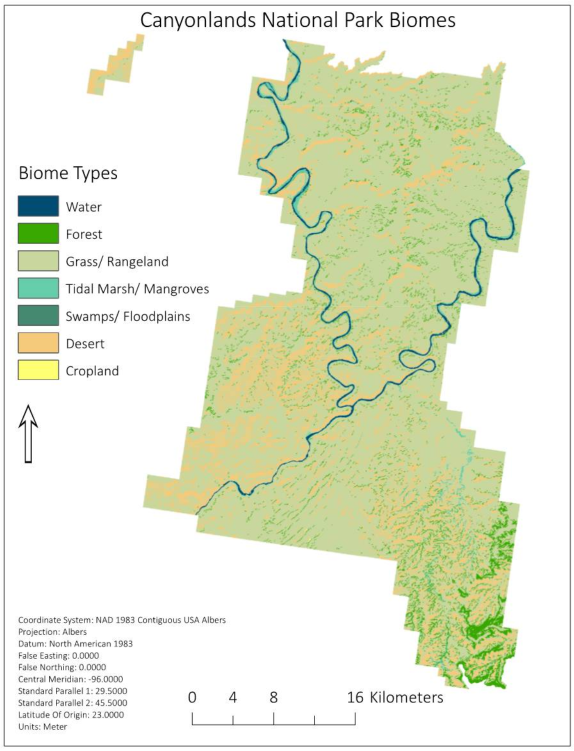
Canyonlands Park provides an example of our benefits transfer approach. The NLCD land cover categories (Map 1) are reclassified to the biomes of the TEEB database (Map 2). Canyonlands National Park is in the 15th largest park by area out of the 46 parks analyzed. Canyonlands NP is in arid,





southeastern Utah, near Arches National Park. The area is famous for its rusty red rocks and other-worldly rock formations. The Green and Colorado Rivers converge in the park. The dominating land cover type for Canyonlands National Park is "Shrub/ Scrub", followed by "Desert" (Map 1). The most prevalent biome type is "Grass/ Rangeland", followed by "Desert" (Map 2). The rivers support some wetland biomes, which constitute around 45% of the park's total annual ecosystem service value. The ecosystem service value of Canyonlands National Park is $869,372,685 per year.

Everglades National Park, located on the southern tip of Florida, is also a World Heritage Site thanks to its unparalleled biodiversity. Map 3 shows extensive "Water", "Woody Wetlands", and "Emergent Herbaceous Wetlands" land cover types. 99% of the biome types at the park are "Marsh", "Swamp", or "Water", shown in Map 4. The ecosystem service value of Everglades National Park, $42,279,172,811 per year, constitutes more than half of the ecosystem service value of all the National Parks combined. The value of water ecosystem services account for 6% of the park's

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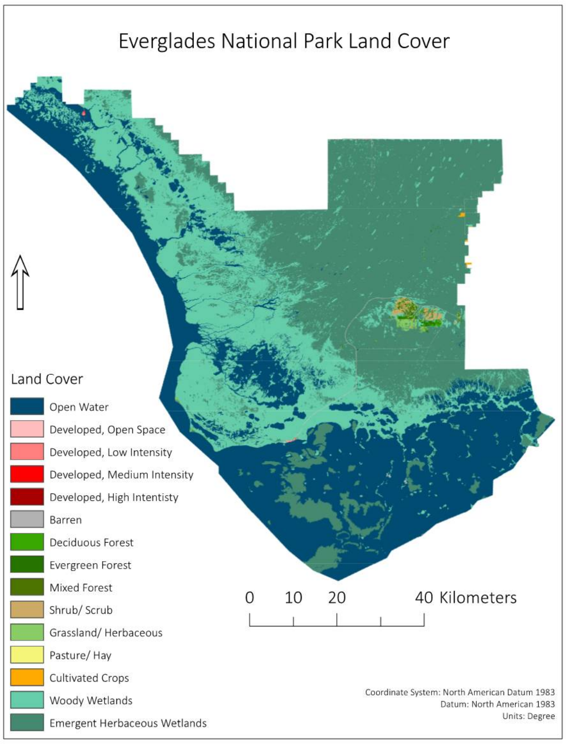
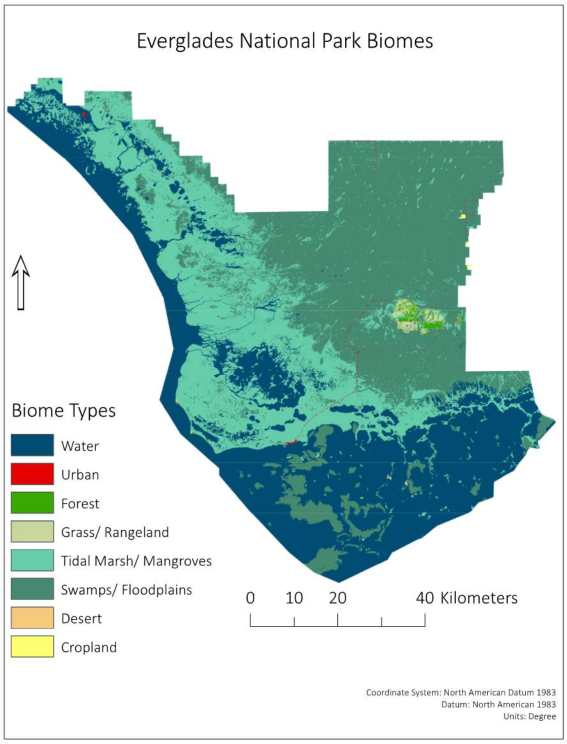
total annual ecosystem service valuation, while wetlands account for around 94% of the park's total valuation.

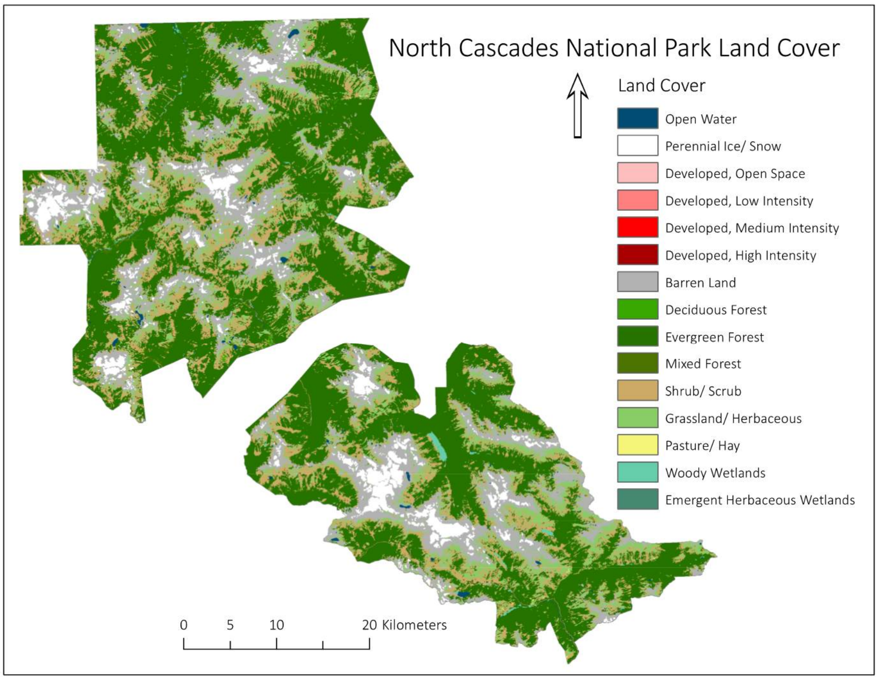


Map 1. Everglades National Park land cover

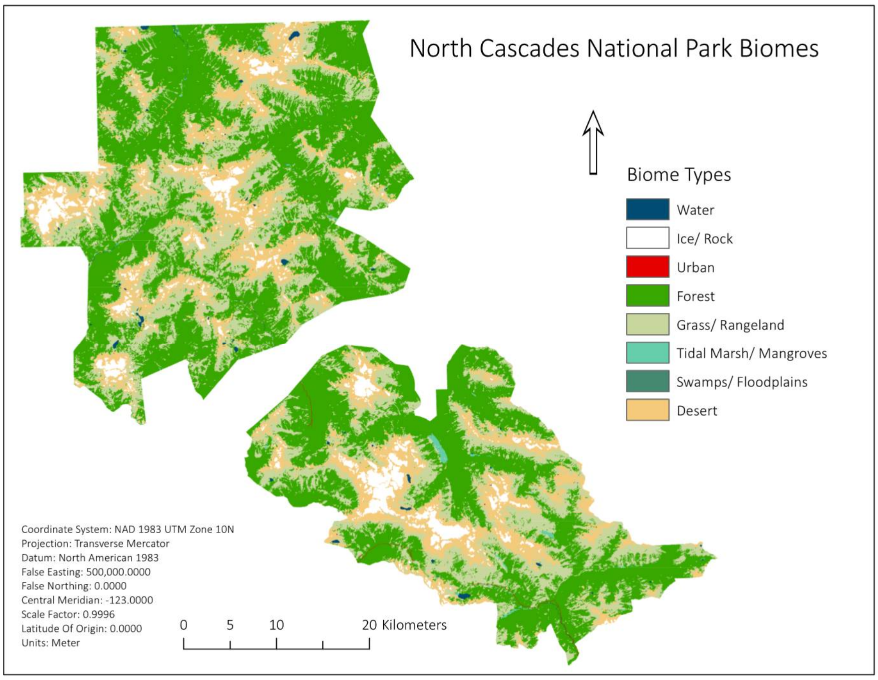


Map 2. Everglades National Park biome types

North Cascades National Park in Washington is mountainous and home to hundreds of glaciers. The footprint of the mountain range is visible in Map 5, which shows the land cover data of the park. The annual ecosystem service value of North Cascades National Park is $743,555,127 per year. It is the 12th largest park by area in this study. North Cascades has one of the largest spatial extents of the "Forest" biome type out of all the National parks studied. The forest biome accounts for 50% of the park's total ecosystem service valuation and covers just under 50% of the park. Around 5% of the park is covered by "Perennial Ice/ Snow". While marshes cover less than 1% of the park's land, they make up nearly 16% of the park's annual ecosystem service valuation.



Map 3. North Cascades National Park land cover



Map 4. North Cascades National Park biome types

There are many issues associated with the reduction of the NLCD classes to the Biomes of the TEEB. The most abundant biome in the parks was "Grass/ Rangeland". This is partially due to the classification of land cover types. Death Valley National Park has more pixels classified as "Grass/ Rangeland" than any other park by a factor of 10, while most people know Death Valley is America's most famous desert. The NLCD calls "Shrub/Scrub" a land cover type where vegetation is, "less than

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5 meters tall… stunted from environmental conditions" [14]. This land cover type was characterized as the "Grass/ Rangeland" biome type because we see this type of vegetation in grasslands, in the alpine, and in deserts. Similarly, the "Barren" land cover type includes scarps, glacial debris, talus, and slides, as well as desert pavement and sand dunes, which are found in desert and alpine landscapes. The "Barren" land cover type was reclassified to "Desert". This oversimplification means "Desert" biomes were reported in alpine areas where a visual analysis might show a different biome type. This limitation did not ultimately affect the results of the valuation because "Desert" biomes are currently valued at zero dollars. These issues of classification are unavoidable and introduce a variety of uncertainties into analyses of this type.

4. Discussion

There are many potential criticisms of these valuations from a technical point of view. Ecosystem service values for the same biome vary spatially [5]. The ecosystem service values used here were intended for a global scale, and even regionally specific ecosystem service values would not be as accurate as ecosystem service values specific to each National Park [17]. The spatial resolution of the data means not all variation in land cover within the parks was captured [18]. These sources of error could result in higher or lower estimates of the National Parks' ecosystem service values. Other errors may have arisen from the reclassification of the biomes from the NLCD data.

For example, there was no distinction between forest types or marine vs freshwater biomes. Thus, all types of "forest" were simplified to a single forest ecosystem service average, and all water land cover was assigned the "river/lake" ecosystem service value because there is more freshwater in the National Parks than saltwater. Conversely, the land cover data set returned different levels of intensity for urban land cover. The ecosystem service value dealing with urban land cover from Costanza et al. does not make this distinction, so all levels of urban development were assigned the same ecosystem service value. This study did not incorporate a recent urban ecosystem service valuation of New York City's central park which is currently the highest estimate of per hectare ecosystem service value ever published ($70 million per hectare per year) [19]. This astronomical estimate of urban ecosystem service value was not included in this study and would not have mattered much because there is very little urban area within the parks. This estimate of Central Park's ecosystem services is very high because the value results from the significant interaction of human, social, built, and natural capital that exists in Central Park. A study conducted by researchers at Colorado State and Harvard surveyed Americans as to what they would pay for the preservation of the parks. Their estimate of the total annual value of our National Parks was $62 Billion / year. This estimate is likely also amplified by the significant interaction of human, social, built, and natural capital that takes place in the parks.

The take home point of this study is that a plausible and conservative estimate of the value of the ecosystem services provided by the lands within the United States National parks is roughly $80 billion / year. This estimate is consilient with the CSU-Harvard (NPS-TEV) study that estimated the annual value of the National parks at $62 billion [20]. The $62 Billion figure was based primarily on analysis of surveys that asked Americans what they would be willing to pay on an annual basis in addition to their existing taxes to preserve the park system and its programs. In fact, the NPS_TEV study validates the idea that our estimate is conservative because we include many ecosystem services that are not well perceived by the public [21].

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Ongoing land degradation, climate change, ocean acidification, and land cover changes are reducing the quantity and quality of ecosystem services being provided globally [4-5]. These losses are taking place because we do not value ecosystem services at a sufficient level to preserve them. Many individuals, NGOs, and nations of the world are progressively more involved in studies, legislation, and increasingly urgent expressions of concern regarding myriad damages to the world's environment that are ongoing and likely accelerating [22-24].

A primary reason for this loss of natural capital is our collective inability to appropriately value our natural environment. Valuations of ecosystem services that eclipse the dollar size of market economies are regarded as not credible (particularly by economists); however, there is growing consensus that our market based economic systems have failed to serve as rational stewards of the environment. We present these numbers as a reasonable starting place to discuss a new allocation of resources in which we preserve the ability of our environment to support our society, economy, and individual wellbeing. We regard plausible valuation of ecosystem services as a good starting point for environmental politics [25] and suggest that discussions of levels of funding for our national parks is fundamentally in the domain of environmental politics.

In addition, this study only included areas under the National Park Service's "National Park" classification. Of course, most, if not all, areas they manage provide ecosystem services, from historical battlefields to recreation areas to lakeshores. This study only included areas within the contiguous 48 states. There are several National Parks in Alaska, American Samoa, the US Virgin Islands, and Hawaii that were not considered in this study, including the largest National Park in the system, Wrangell-St. Elias National Park, which is 13.2 million acres [1].

Even if the ecosystem service values were overestimated in this study, a lower estimated value would be considerably higher than the amount spent on the National Parks by the federal government. More importantly, only a small fraction of the areas maintained by the National Park Service were analyzed in this study. A study done of ecosystem service values of all the wild spaces managed by the Park Service would undoubtedly return an even higher value. Given that the annual budget of the National Park service is just under $3 billion, and the value of their ecosystem services is more than 28 times that, we suggest they are grossly underfunded in terms of return on investment. If we regarded the National Parks to be more than a revenue stream generated by visitors, and regarded them as natural capital generating a revenue stream of ecosystem services which have significant monetary value, it is likely that greater investments in the National Parks would be less controversial. If the National Parks were treated as built capital, and we used annual ecosystem services alone to account for gross revenue, we would provide at least $25 billion for an operating budget (30% of $84 billion) according to industry standard property management fees.

Critics like Douglas McCauley argue that market-based conservation strategies do not work. He argues "*market-based mechanisms for conservation are not a panacea for our current conservation ills*"; however, ecosystem services bridge the gap between pragmatic economics and optimistic environmentalism [11]. Assuming that the goal of ecosystem service valuation is to prove that, "*nature is only worth conserving when it is, or can be made profitable*", is in fact the opposite of the purpose of this type of analysis [11]. Until our collective mindset develops to place value on unimpaired nature such that conservation and preservation are considered moral imperatives, ecosystems services are a tool that can be used to justify protecting our environment.

5. Conclusions

In this paper we present a valuation of the United States National Parks from an ecological economics perspective. We do this because our failure to consider the value of ecosystem services provided by the National Parks makes us fail to quantify and appreciate the contributions our parks make to our environment, economy, and society. This oversight allows us to continue to underfund a valuable part of our natural capital and consequently damage our supporting environment, national heritage, monetary economy, and many of our diverse cultures. We estimate the value of the ecosystem services of the 48 National Parks in the contiguous United States to annually produce over $80 billion in provisioning, regulating, supporting, and cultural services. If the natural infrastructure 'asset' that is our national park system had a budget comparable to a piece of commercial real estate of this value, the annual budget of the National Park Service would be roughly an order of magnitude larger at something closer to $30 billion rather than $3 billion. Ecological economics argues for several specific changes to the dominant economic paradigm. Three guiding principles inform the changes we need to make. First, we must live within planetary boundaries (e.g. there are limits to growth, earth is a finite planet, etc.). Second, we must equitably distribute wealth and income throughout space and time (e.g. meet a John Rawls '*veil of ignorance*' test). Third, we must allocate resources efficiently (e.g. traditional economics associated with maximizing utility through resource allocation). Living within planetary boundaries is primarily an assessment of scientists who have expertise that is relatively objective. In this area Richard Feynman's quote seems appropriate: "*Reality must take precedence over public relations, for nature cannot be fooled*". The current scientific consensus suggests we are failing to meet the standard of the first principle. Equitable distribution is a messier question involving public relations and social negotiations. A growing literature on the negative consequences of inequality [26-27] and social movements (Occupy Wall Street, Women's March, Black Lives Matter) suggest we are failing to meet the standard of the second principle. The third principle of optimal allocation is working in a limited way through the dominant economic paradigm; however, it also fails because it is not subservient to the first two principles and results in malvaluation, misallocation, short-termism, and unacceptable levels of inequality and poverty [27]. Recognizing the ecosystem service value of our national parks and increasing the budget of our national park system to support and maintain them is a small step we can make to live within the guiding principles of ecological economics. It will not only create jobs but help us chart a path to a more sustainable and desirable future.

Author Contributions: Each author made a contribution to this paper such that the paper would not have been completed without their input. A breakdown of our contributions could roughly be described as follows: “conceptualization, PS, SD, and SA.; methodology, SD and SA; validation, PS; data curation, PS.; writing—original draft preparation, SD; writing—review and editing, PS.; visualization, SD and SA.; supervision, PS.; project administration, PS.;

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Appendix A

Detailed National Park Biome Extent and Ecosystem Service Value

UNIT_NAME	Water	Ice/Rock	Urban	Forest	Grass/ Rangeland	Tidal Marsh/ Mangroves	Swamp/ Floodplains	Desert	Tundra	Cropland	Park Area (pixels)
Acadia	5,411	0	9,292	123,491	2,973	14,547	4,359	1,128	13,237	0	174438
Big Bend	592	0	13,617	61,261	708	9,107	852	21,574	3,541,998	2,525	3652234
Biscayne	563,075	0	87	1,617	0	31,414	157,966	0	6	0	754165
Canyonlands	22,003	0	0	74,053	35,496	22,470	385	249,960	1,101,548	95	1506010
Capitol Reef	30	0	3,951	127,690	83,286	871	0	294,068	587,753	0	1097649
Crater Lake	58,536	0	7,589	673,537	6,422	0	0	40,132	31,179	0	817395
Death Valley	51	0	33,476	361,922	30,894	2,803	13	722,864	14,140,625	205	15292853
Everglades	2,307,344	0	9,504	20,944	11,639	1,925,627	2,622,794	1,554	16,916	2,148	6918470
Grand Canyon	35,140	0	12,811	1,105,126	134,396	8,640	2,033	734,016	3,397,942	104	5430208
Grand Teton	142,499	4,433	10,756	464,974	233,968	29,401	31,702	56,384	419,326	6	1393449
Great Basin	32	1,157	992	292,141	5,744	156	5	27,871	19,006	0	347104
Great Smoky Mountains	18,391	0	21,367	2,269,789	10,720	1,188	0	773	8,657	510	2331395
Guadalupe Mountains	8	0	952	85,301	3,483	0	0	17,677	287,759	0	395180
Isle Royale	1,870,766	0	0	448,294	245	121,032	9,222	8,189	13,782	0	2471530
Mount Rainier	7,031	126,222	8,714	666,369	26,864	8,912	82	88,538	125,016	0	1057748
North Cascades	7,252	105,505	1,158	1,103,359	245,528	6,788	326	393,359	389,693	0	2252968
Olympic	75,640	152,584	11,437	3,254,129	57,632	56,695	1,876	212,356	288,264	0	4110613
Redwood	34,301	0	14,380	439,656	8,977	2,756	1,151	6,289	11,971	504	519985
Rocky Mountain	3,115	152,940	10,514	672,286	164,871	13,775	4,028	166,024	12,677	0	1200230
Saguaro	37	0	4,402	92,035	168	7	0	220	323,342	0	420211
Shenandoah	5	0	22,694	846,030	127	0	0	217	0	1	869074
Black Canyon of the Gunnison	274	0	74	93,569	1,232	15	0	270	45,556	0	140990
Mammoth Cave	2,182	0	573	221,925	1,252	4,695	187	0	37	0	230851
Yosemite	31,871	2,380	14,152	1,687,611	118,943	33	15,992	567,413	913,173	24	3351592
Great Sand Dunes	255	0	1,855	13,014	17,536	5,257	6,377	97,435	222,017	84	363830
Wind Cave	0	0	2,317	38,807	60,730	0	122	0	25,374	0	127350
Glacier	117,536	46,159	7,964	2,741,088	107,346	2,675	537	468,561	1,040,579	0	4532445
Arches	129	0	1,945	3,649	8,489	3,381	0	33,342	292,866	0	343801
Channel Islands	533,575	0	3,099	6,283	249,625	63	3,891	11,180	293,751	0	1101467
Joshua Tree	0	0	12,621	5,652	59,573	0	0	231,209	3,258,161	0	3567216
Voyageurs	330,347	0	609	420,308	384	116,484	41,793	0	9,809	35	919769
Theodore Roosevelt	3,561	0	4,577	62,324	174,027	9,049	3,090	20,104	36,641	3,111	316484
Congaree	1,012	0	296	6,257	185	100,543	746	0	13	5	109057
Hot Springs	5	0	1,715	22,670	174	0	0	34	0	0	24598
Petrified Forest	182	0	5,804	17	117,151	468	28	2,182	877,467	44	1003343
Dry Tortugas	259,100	0	5	0	63	123	19,142	131	0	112	278676
Zion	0	0	4,657	330,871	329	722	49	108,461	220,778	0	665867
Badlands	667	0	8,670	3,417	454,772	260	59	620,891	364	5,528	1094628
Bryce Canyon	0	0	3,324	110,872	1,131	189	0	23,705	22,602	0	161823
Cuyahoga Valley	2,707	0	18,174	108,180	8,444	9,539	107	44	298	2,721	150214
Carlsbad Caverns	0	0	751	39,720	4,039	0	0	12	165,833	56	210411
Lassen Volcanic	8,664	0	5,657	345,800	1,019	0	827	24,702	95,830	0	482499
Yellowstone	465,177	351	29,519	4,541,815	926,547	79,247	178,931	31,545	3,636,782	0	9889914
Mesa Verde	79	0	2,766	79,019	24,608	764	22	177	133,929	0	241364
Kings Canyon	23,516	2,385	3,785	581,351	111,260	283	2,238	767,848	572,189	26	2064881
Sequoia	9,923	368	5,913	841,408	75,860	0	1,981	462,970	431,691	0	1830114
Total Pixel Count	6,942,021	594,484	338,515	25,489,631	3,588,860	2,589,979	3,112,913	6,515,409	37,026,437	17,844	86216093
Area (in hectares)	624,782	53,504	30,466	2,294,067	322,997	233,098	280,162	586,387	3,332,379	1,606	7,759,448
*1 pixel = 900 m2 –> 900 m2 = 0.09hc											
Area (in km2)	6,248	535	305	22,941	3,230	2,331	2,802	5,864	33,324	16	77,594

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Appendix B

Land Cover Reclassification Scheme and Corresponding ESV

Land Cover Type	Biome Type	ESV (2007$/hc/yr)
Water	Water	12,512
Perennial Ice/ Snow	Ice/Rock	0
Developed, Open Space	Urban	6,661
Developed, Low Intensity	Urban	6,661
Developed, Medium Intensity	Urban	6,661
Developed, High Intensity	Urban	6,661
Barren Land	Desert	0
Deciduous Forest	Forest	3,800
Evergreen Forest	Forest	3,800
Mixed Forest	Forest	3,800
Shrub/ Scrub	Grass/ Rangeland	4,166
Grassland/ Herbaceous	Grass/ Rangeland	4,166
Pasture/ Hay	Grass/ Rangeland	4,166
Cultivated Crops	Cropland	5,567
Woody Wetlands	Tidal Marsh/ Mangrove	193,843
Emergent Herbaceous Wetlands	Swamps/ Floodplains	25,681

References

1. NPS Overview 2017. Available online: https://www.nps.gov/aboutus/news/upload/NPS-Overview-12-05-17.pdf (accessed on 27 October 2018).
2. Daly, H. E., & Farley, J. C. (2011). Ecological economics: Principles and applications (2nd ed.). Washington: Island Press.
3. Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., et al. The value of the world's ecosystem services and natural capital. *Nature*, (1997) *387*(6630), 253-260. doi:http://dx.doi.org/10.1038/387253a0
4. Costanza, De Groot, Sutton, Van Der Ploeg, Anderson, Kubiszewski, Farber, and Turner. "Changes in the Global Value of Ecosystem Services." *Global Environmental Change* (2014) 26, 152-58.
5. Sutton, P. Space matters: Exploring problematic spatial issues in the valuation of ecosystem services. Valuing Ecosystem Services: Methodological Issues and Case Studies; Ninan, KN, Ed, (2014) 132-147
6. Sutton, P. C., Anderson, S. J., Costanza, R., & Kubiszewski, I. The ecological economics of land degradation: Impacts on ecosystem service values. Ecological Economics (2016) 129, 182-192.
7. Pitman, S. D., Daniels, C. B., & Sutton, P. C. Ecological literacy and socio-demographics: who are the most eco-literate in our community, and why?. International Journal of Sustainable Development & World Ecology, (2018) 25(1), 9-22.
8. Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., ... & Polasky, S. Assessing nature's contributions to people. Science, (2018) 359(6373), 270-272.
9. de Groot, R., Costanza, R., Braat, L., Brander, L., Burkhard, B., Carrascosa, J. L., ... & Hein, L. Ecosystem Services are Nature's Contributions to People: Response to: Assessing nature's contributions to people. *Science Progress*, (2018) *359*:6373.
10. Daly, H. E., & Farley, J. C. Ecological economics: Principles and applications (2nd ed.). Washington: Island Press. (2011).
11. Mccauley, D. J. "Selling out on Nature." *Nature* 443.7107 (2006): 27-28.
12. *A Call to Action 2016*. Available online https://www.nps.gov/calltoaction/ last accessed on 25 Aug. 2018.
13. Duncan, S. and Sutton, P. C. An Ecosystem Service Valuation of Yellowstone and Grand Teton National Parks. N.p., Jan. 2017.
14. Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. *Photogrammetric Engineering and Remote Sensing*, v. 81, no. 5, p. 345-354
15. Anderson, S., Giordano, A., Costanza, R., Kubiszewski, I., Sutton, P., Maes, J., & Neale, A. (2017). 5.7. 2. National ecosystem service mapping approaches. Mapping Ecosystem Services, 237
16. TEEB, The Economics of Ecosystems and Biodiversity: Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. (2010) Available online http://www.teebweb.org/ (accessed 27 October 2018).
17. Burhard, B. & Maes, J. Mapping ecosystem services. *Advanced Books*, 2017, 1. Jg., S. e12837.
18. Burhard, B. & Maes, J. Mapping ecosystem services. *Advanced Books*, 2017, 1. Jg., S. e12837.
19. Sutton, P. C., & Anderson, S. J. Holistic valuation of urban ecosystem services in New York City's Central Park. Ecosystem Services, (2016) 19, 87-91.
20. Haefele, M, Loomis, J. & Bilmes, LJ (2016) Total Economic Valuation of the National Park Service Lands and Programs: Results of a Survey of The American Public. Available online: https://www.nationalparks.org/sites/default/files/NPS-TEV-Report-2016.pdf (accessed on 26 October 2018.
21. Pitman, S. D., Daniels, C. B., & Sutton, P. C. Characteristics associated with high and low levels of ecological literacy in a western society. International Journal of Sustainable Development & World Ecology (2018) 25(3), 227-237.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 29 October 2018 doi:10.20944/preprints201810.0661.v1

22. IPCC: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. (2013)
23. MEA: Millennium Ecosystem Assessment (Program). Ecosystems and human well-being. Washington, D.C: Island Press. (2005).
24. United Nations Environment Programme., & United Nations Environment Programme. Global environment outlook GEO 5: Environment for the future we want. Nairobi, Kenya: United Nations Environment Program. (2012).
25. Jadhav, A., Anderson, S., Dyer, M. J., & Sutton, P. C. Revisiting ecosystem services: Assessment and valuation as starting points for environmental politics. Sustainability (2017) 9(10), 1755.
26. Wilkinson, R. G., & Pickett, K. The spirit level: Why greater equality makes societies stronger. New York: Bloomsbury Press (2010).
27. Piketty, T. Capital in the twenty-first century. Cambridge Massachusetts :The Belknap Press of Harvard University Press. (2014).