

The Global Value of Coastal Wetlands and River Delta

Mushran Siddiqui, MscEEM
Student
Department of Economics
Bob Gaglardi School of Business and Economics
Thomspon Rivers University
Kamloops, British Columbia
Email: siddiquim21@mytru.ca

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Abstract

This study examines the economic valuation of ecosystem services provided by coastal wetlands and river deltas. Utilizing the Ecosystem Services Valuation Database (ESVD) developed by Brander et al. (2023), this report investigated the annual economic value of these vital biomes on a global scale. The literature review revealed the importance of coastal wetlands in storm and flood protection, carbon sequestration, biodiversity conservation, and climate regulation. Despite their importance, this study highlights an alarming trend of habitat loss, aggravated by human activities and environmental changes, underpinning an urgent call for enhanced conservation efforts. Through a comprehensive review of 785 observations, the research demonstrates significant variability in the valuation of ecosystem services, with regulation services emerging as the most valuable. This variability reflects the complex relationship between natural resource depletion and the four main ecosystem services. The findings advocate for immediate policy interventions to preserve these irreplaceable natural assets, ensuring their continued contribution to global ecological stability and human well-being.

Keywords: Ecosystem Services Valuation, Biome, Conservation, Resource Depletion

1. Introduction

Coastal wetlands and river delta biomes are essential ecosystems that play significant roles in carbon sequestration, biodiversity conservation, and climate regulation. They also shield coastal populations from floods and intense storms as salt marshes and mangroves provide nature-based risk mitigation (Van Coppenolle & Temmerman, 2020). Coastal wetlands act as crucial carbon sinks, sequestering carbon and aiding climate change mitigation. A meta-analysis comparing CO₂ fluxes between inland and coastal wetlands highlights these ecosystems' essential role in global carbon cycling (Tang et al., 2022; Lu et al., 2016). Coastal wetlands, including marshes and mangroves, are known as blue carbon ecosystems due to their exceptional carbon sequestration capabilities (Gao et al., 2022). They are also essential for maintaining ecosystem services and supporting biodiversity (Fastelli et al., 2017). River deltas, such as the Lena River Delta in Siberia, are characterized by diverse biomes ranging from river channels to marshes and peat swamps, supporting unique flora and fauna (Kutzbach et al., 2007). These deltas are essential for carbon exchange with the atmosphere and serve as critical habitats for various species, including migratory fishes (Bailly et al., 2021).

These biomes are particularly vulnerable to environmental changes such as warming temperatures, rising sea levels, and human activities like agriculture and urbanization (Lazarus, 2017; Nill et al., 2019). For example, the Yellow River Delta in China has experienced wetland loss due to land use change, aquaculture pond expansion, and flow-sediment regulation, as shown in Fig.1 (Zhu et al., 2018). These changes have led to the transformation of natural wetlands into farmland and aquaculture ponds, impacting the biodiversity and ecological functions of the region (Yu et al., 2016; Chunying et al., 2018). Significant land subsidence and wetland loss were observed in the Po River Delta, Italy, mainly due to natural processes and anthropogenic activities (Gaglio et al., 2016).

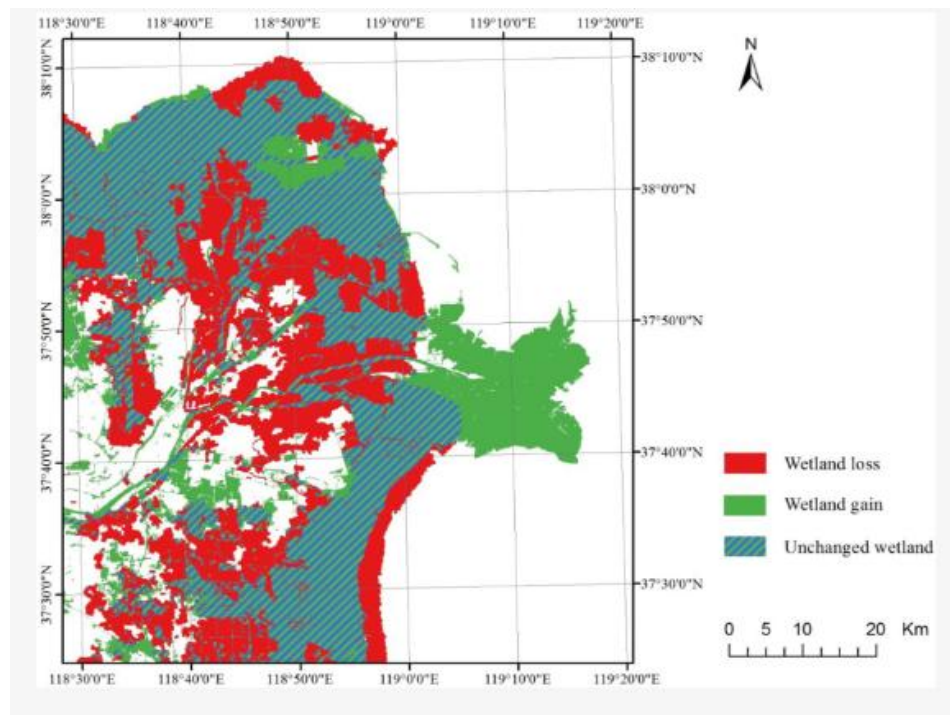


Fig.1. Map showing changes in wetlands in the Yellow River Delta over the past four decades. Reprinted from (Zhu et al., 2018)

Therefore, this paper explores the valuation of coastal wetlands and river deltas for 2023 and compares it to the study conducted by Costanza et al. (2014) and De Groot et al. (2020). The rest of the paper is organized as follows: Section 2 introduces the methodology and discusses data extraction, ecosystem services and evaluation of the global surface area of the biome. Section 3 evaluates the values of various ecosystem services per hectare

(ha) per year, and using the surface area, the annual flows of such values are obtained. Finally, conclusions are drawn, and potential future policies are discussed in Section 4.

2. Methodology

The surface area of the World's coastal wetlands and river delta were collected from published journal articles. The price per ha per year was obtained from Costanza et al. (2014 and De Groot (2012), updated to 2020 Int \$, De Groot et al. (2020), and the Ecosystem Services Valuation database (ESVD) developed by (Brander et al., 2023).

2.1. The Ecosystem Services Valuation Database (ESVD)

The Ecosystem Services Valuation Database (ESVD) aims to develop a highly reliable and easily accessible repository of information on the economic benefits of ecosystems and biodiversity, along with costs related to the loss of nature. The main goal is to support decision-making on nature conservation, restoration, and sustainable land management. The ESVD currently contains 9,500 value records from over 1100 studies distributed across all biomes, and coastal wetlands and river delta data were collected from 247 studies, as shown in Fig.2 (Brander et al., 2023).



Fig.2. The map shows 1168 observations for coastal wetlands and river delta from 247 studies (Brander et al., 2023).

2.2. Data Extraction

The ESVD data consisted of different biomes interacting, which needed to be filtered out to minimize the overlap. The filtering process is shown in the flowchart in Fig.3.

Initially, 1168 observations were extracted, with coastal wetlands and river delta as primary and as primary but interacting with other biomes. The lesser-weight secondary observations were then discarded, which resulted in 854 observations containing only the primary data. Biome with Coastal Wetlands and River Delta as a primary category is shown in Table 1. The data is further refined by only taking coastal wetlands and river delta biome, resulting in 785 observations overall.

Table 1: ESVD2.0 Biome with Coastal Wetlands and River Delta as a primary category.

Coastal wetlands and river deltas;
Coastal wetlands and river deltas; Coastal inlets
Coastal wetlands and river deltas; Coastal inlets; Freshwater lakes
Coastal wetlands and river deltas; Rivers and streams; Freshwater lakes
Coastal wetlands and river deltas; Seasonal floodplain marshes
Coastal wetlands and river deltas; Seasonal floodplain marshes; Rivers and streams
Coastal wetlands and river deltas; Seasonal floodplain marshes; Rivers and streams; Freshwater lakes
Coastal wetlands and river deltas; Shelf Sea and coral reefs
Coastal wetlands and river deltas; Shelf Sea and coral reefs; Shorelines; Salt lakes

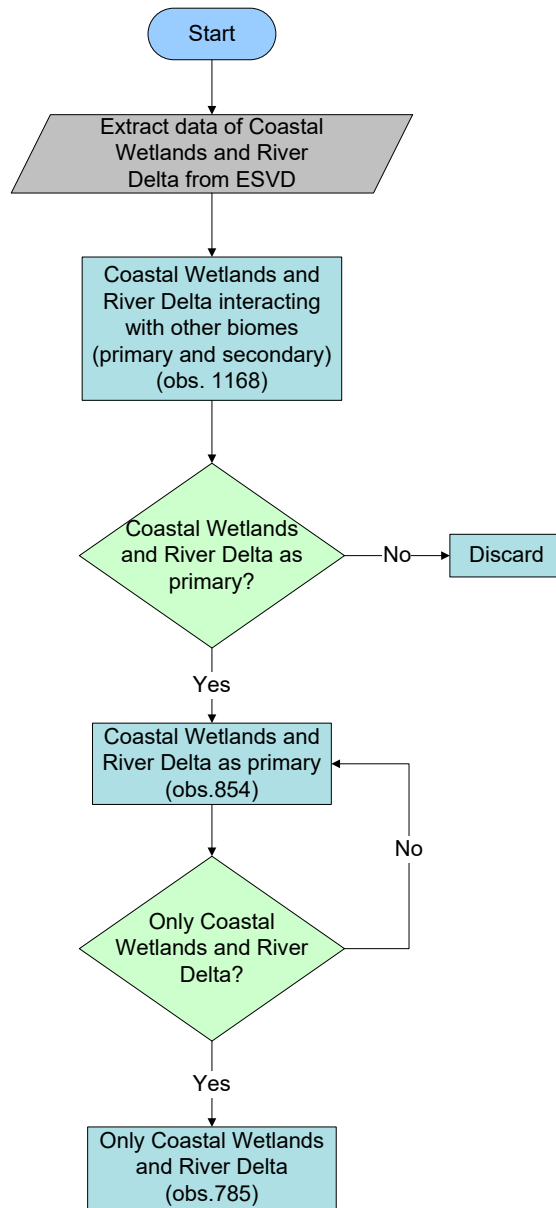


Fig.3. Data filtering process

The studies were conducted on various continents, as shown in Table 2. Asia had the most significant proportion of the studies, followed by Europe and North America. The study conducted by (Davidson et al., 2018) also aligns with Table 2, as most of the coastal wetlands and river deltas are situated in these parts of the world.

Table 2: Continent location of the studies.

Continents	Coastal Wetlands and River Delta interacting with other biomes (primary and secondary)	Coastal Wetlands and River Delta interacting with other biomes (primary)	Only Coastal Wetlands and River Delta
Africa	113	105	83
Asia	470	398	386
Europe	227	130	111
Global	2	1	1
North America	190	107	104
Oceania	62	29	25
South America	104	84	75
Total	1168	854	785

2.3. Ecosystem Services

Ecosystem Services describe ecosystems' biological, habitat, or systemic characteristics and functions. The products and services ecosystems provide to human populations, directly or indirectly, include food and waste assimilation (Costanza et al., 1997). The ecosystem services 1 (ES1) category was used to evaluate ecosystem services, while some biome studies provided values for multiple ecosystem services together as a combined service (i.e., 34.2%). The ecosystem services are divided into four categories, as shown in Table 3.

Table 3: Ecosystem services.

Provision	Regulation	Maintenance and Support	Culture
Food	Air Quality Regulation	Maintenance of genetic diversity	Opportunities for recreation and tourism
Genetic Resources	Biological Control	Maintenance of life cycles	Aesthetic information
Medicinal Resources	Climate Regulation	Habitat/Refugia	Existence, bequest values
Raw Materials	Erosion Prevention	Soil Formation	Information for cognitive development
Water	Regulation of water flows	Maintenance of soil fertility	Inspiration for culture, art and design
	Gas Regulation	Pollination	Spiritual experience
	Moderation of extreme events		
	Waste treatment		

2.4 Coastal Wetlands Global Surface Area

Costanza et al., (2014) divided wetlands into two sub-categories: (i) Tidal marsh/Mangroves and (ii) Swamps/Floodplains. Mangroves and tidal marshes are classified as coastal wetlands because of their relationship to salty environments and their coastal position. In contrast, as swamps and floodplains are located away from the coast and are predominantly impacted by freshwater sources, they are usually regarded as inland wetlands. As this report is focused on coastal wetlands, swamps and floodplains are not included in the analysis. The following information has been obtained from (Davidson et al., 2019), an updated version of Davidson et al., (2018).

Table 4: Global areas of different coastal wetland classes.

Coastal Natural Wetlands	Global Area × 10 ⁶ km ²	Global Area in a million ha
Unvegetated tidal flats	0.128	12.8
Salt marshes	0.055	5.5
Coastal deltas	0.030	3.0
Mangroves	0.138	13.8
Total Global Area	0.351	35.1

The global surface area of coastal wetlands thus accumulates to 35.1 million hectares. The following Table 5 compares this data with Costanza et al., (2014):

Table 5: Change in surface area of coastal wetlands.

Biome	Area (e6 hectares)			% change (1997-2011)	% change (2011-2020)	% change (1997-2020)
	1997	2014	2020			
Coastal Wetlands	165	128	35.1	-22.42%	-72.58%	-78.72%

Costanza et al., (1997) allocated 165 million hectares (ha) to coastal wetlands (Table 5) and in the 2014 study coastal wetlands declined to 128 million ha, a 22.4% degradation. Davidson et al., (2019) explored into the changes in global wetland areas from 1996 to 2016, observing a decrease in unvegetated tidal flats by 3.12%, mangroves by 4.3%, and coastal deltas by 52.4%. The global surface area of coastal wetlands has decreased significantly by 78.72% over the last 23 years, as shown in Table 5. This trend is alarming and indicates severe environmental degradation or loss of natural spaces, and the analysis by Liu et al. (2023) also supports these findings. The proportion of the wetlands' surface area degradation is mainly due to negatively affected agriculture-based practices, as found in Global Wetland Outlook (2023), which cause extreme water stress, as shown in Fig.4.

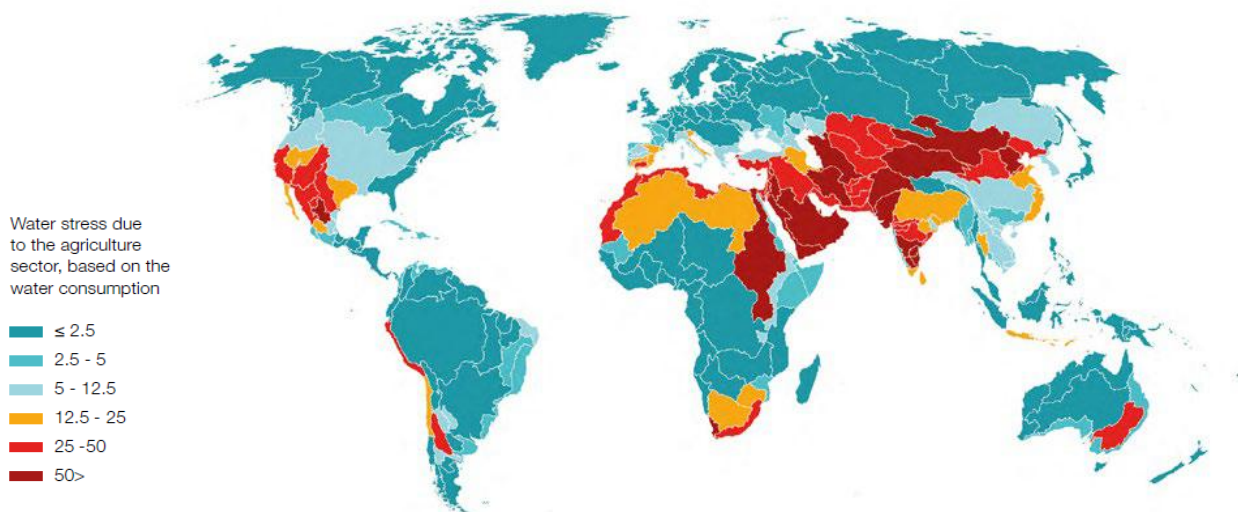


Fig.4. Contribution of the agricultural sector to the level of water stress on coastal wetlands, reprinted from GWO Special Edition 2021. (n.d.). Global Wetland Outlook. Retrieved April 3, 2023, from <https://www.global-wetland-outlook.ramsar.org/report-1>.

3. The price per ha per year of coastal wetlands

In this study it is assumed that coastal wetlands or river deltas have the same price per ha per year. These ecosystems are mostly interconnected with numerous shared characteristics. Wetlands retain water, increasing the water age, while deltas trap sediment and control connectivity, impacting biogeochemical processes in coastal areas (Christensen et al. 2020). Therefore, coastal wetlands and river deltas may possess similar values because of their ecological resemblances and the difficulties associated with acquiring individualized valuations for these intricate ecosystems. The grouping of these entities is carried out for the sake of convenience, due to the limited availability of data. Nonetheless, notable variances exist in their geographic, hydrological, and biological attributes, which could warrant distinct economic assessments. This presents a constraint, highlighting the necessity for prospective studies to ascertain the valuation of each biome.

The analysis of 785 observations in Table 6 focuses on the price per ha per year on the primary biome, namely coastal wetlands and river deltas, emphasizing their unique value among ecosystems. The appendix further explores their interactions with various other secondary biomes. In 2023, the average value of ecosystem services varied widely, with a mean of \$86,743 per hectare per year and a median of \$11,897, indicating substantial variability across different services. Moreover, there is a significant difference between the minimum and maximum values. Regulation services emerged as the most valuable category, with an average value of \$43,299 per hectare per year, followed by cultural, provisioning, and supporting services, with the lowest average value of \$9,536 per hectare per year. This study's findings differ from Costanza et al., (2014), which reported a higher average value, largely due to the exceptionally large impact of waste treatment services at \$202,369 per hectare per year. However, when median values are considered, the analysis of this study is more aligned with previous findings, suggesting that outliers skewed the average values. The study also notes a degree of increase in the value of most services since 2014, attributing this potentially to the decreasing supply of natural resources, which drives up prices. This report also supports the findings from De Groot et al. (2020) for estimating global ecosystem services valuation and is shown in Table 6, where they categorized "Coastal Systems" as a biome. This categorization notably includes a broad spectrum of coastal wetlands like sand dunes, beaches, tidal marshes, and mangroves, among others. The inclusion of these diverse ecosystems in De Groot et al. (2020) report explains the similarity with this study in the average valuation per hectare per year and highlights the predominance of coastal wetlands in the analysis. The total global flow rate in trillion dollars is also computed, as shown in Table 7, to find the potential impact of this biome on the world's economy.

This report emphasizes that the 2014 average value discussed in Table 6, reported by Costanza et al., is notably affected by outliers, particularly in waste treatment services. Moreover, it is important to recognize that Table 6's values in this study, which cover both coastal wetlands and river deltas, are compared to Costanza et al.'s research focusing solely on coastal wetlands. This discrepancy introduces a limitation in precisely comparing the two studies. However, it is to be noted that mangroves and marshes in the ESVD database valuations are more weighted with coastal wetlands than river deltas.

Table 6: Mean standardized values per ecosystem services of Coastal Wetlands and River Delta (Int\$/hectare per year; 2020 price levels).

	Ecosystem Services	Costanza et al. (2014) Coastal Wetlands	De Groot et al. (2020) Coastal Systems	ESVD (2023). Coastal Wetlands and River Delta					
		Avg. Int\$/ha/year	Avg. Int\$/ha/year	Avg. Int\$/ha/year	Median Int\$/ha/year	Standard Error	Minimum	Maximum	No. of Values
Provision	Food	1,387	9,892	8,686	400	2,626	0.02	590,282	285
	Genetic Resources	12	11	11	11		11.07	11	1
	Medicinal Resources	376		173	173		172.80	173	1
	Raw Materials	447	44	5,346	192	3,060	0.15	389,622	131
	Water	1,519	5,172	1,136	440	437	4.99	4,757	12
	Total Provision	3,741	15,119	15,352	1,216	6,123			430
Regulation	Air Quality Regulation		15	467	36	245	0.10	2,094	9
	Biological Control								
	Climate Regulation	81	262	18,928	269	16,309	0.03	880,239	54
	Erosion Prevention	4,904	55	5,064	964	2,207	4.83	47,631	27
	Regulation of water flows		104	1.57	1.57	1.23	0.34	2.80	2
	Gas Regulation								
	Moderation of extreme events	6,679	12,730	15,028	803	7,360	0.34	263,809	43
Waste treatment	202,369	36,556	3,811	1,288	1,017	1.36	27,827	37	
	Total Regulation	214,034	49,722	43,299	3,361	27,139			172
Maintenance & Support	Maintenance of genetic diversity		165	5,605	2,442	3,751	23.14	46,613	12
	Maintenance of life cycles		375	2,903	1,739	1,287	9.85	24,200	18
	Habitat/Refugia	8,101							
	Soil Formation								
	Maintenance of soil fertility		4,019	1,028	525	438	304.88	2580	5
	Total Maintenance & Support	8,101	4,559	9,536	4,706	5,476			35
Culture	Opportunities for recreation and tourism	2,737	7,694	5,102	334	2,313	0.00	199,994	91
	Aesthetic information		268	622	490	82	9.77	996	15
	Existence, bequest values		972	11,083	301	6,775	0.22	126,366	21
	Information for cognitive development		5,683	1,099	1,488	219	4.90	3,038	15
	Inspiration for culture, art and design		145	648	648	0.09	648	0.09	3,890
	Total Culture	2,737	14,762	18,555	2,613	10,037			148
	Total	228,613	84,163	86,743	11,897	48,775			785

There is a trend of decreased values of ecosystem services from 1994 to 2020, as shown in Table 7, which is also supported by other studies. This is concerning for environmental and economic reasons, as the surface area and value per hectare have decreased. Compared with the global GDP in 2022, which is estimated to be Int\$164.5 trillion, the economic contribution of these ecosystems seems minor. However, the implications for future sustainability are profound, indicating a potential decline in quality of life for future generations if current trends persist.

Table 7. Global flow rate for coastal wetlands.

Year	Area (millions of ha)	Total Average Int\$/ha/year	Total Median Int\$/ha/year	Value of ecosystem services per year (in trillions of Int\$)	
				Value-based on average price	Value-based on the median price
1994	165	18,455		3.05	
2011	128	228,613	15,182	29.26	1.94
2020	35.1	86,743	11,897	3.04	0.42

4. Concluding remarks

Coastal wetlands are fragile yet economically valuable ecosystems, offering numerous ecological benefits and services to the communities. Coastal reclamation has fragmented and damaged these areas, impairing their ecological functions (Liu et al., 2020). Additionally, the rapid spread of artificially introduced vegetation (e.g., salt marshes) encroaches on native habitats, further degrading the natural environment and its services (Liu et al., 2023). Losses to coastal wetlands and river delta areas can be attributed to natural processes and human activities. Human-induced factors such as land use changes, population growth, and economic development have significantly impacted these ecosystems. The expansion of agricultural land, urban sprawl, and industrial areas has led to the exploitation and conversion of coastal wetlands into farmland and infrastructure, resulting in the loss of biodiversity and ecosystem services (Yu et al., 2016; Ma et al., 2019). Moreover, anthropogenic activities such as sediment deposition, flow-sediment regulation, and coastal reclamation have had detrimental effects on the structure and function of coastal wetlands in river deltas (Zhang et al., 2022). Excessive reclamation activities can destroy original habitats and lead to wetland degradation, impacting these areas' ecological value (Zhao et al., 2023).

This research emphasizes the significant economic and ecological role of coastal wetlands and river deltas in providing ecosystem services essential to addressing climate change and preserving biodiversity. Despite their value, these biomes face striking threats from land use change, urbanization, and climate change, substantially losing their surface area and functionality. This report found a decrease of 78.72% in surface area of coastal wetlands between 1994 and 2020. This is also reflected in the global flow rate, with lower value of ecosystem services per year in 2020 than in 2014. The results of this study support the need for more robust conservation laws and environmentally friendly land management techniques to save and rebuild these essential ecosystems. Comparing this valuation with earlier research reveals a need for an increasing recognition of their values, necessitating immediate action to protect them.

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Appendix 1: Assessment based on all 854 values.

Table S1. Mean standardized values per ecosystem services of Coastal Wetlands and River Delta and other biomes (Int\$/hectare per year; 2020 price level)

	Ecosystem Services	Costanza et al. (2014) Coastal Wetlands		ESVD 2023 Primary Coastal Wetlands and River Delta interacting with other biomes					
		Avg. Int\$/ha/year	Median Int\$/ha/year	Avg. Int\$/ha/year	Median Int\$/ha/year	Standard Error	Minimum	Maximum	No. of Values
Provision	Food	1387		8258	334	2497	0.02	590281.65	300
	Genetic Resources	12		11	11		11.07	11.07	1
	Medicinal Resources	376		70	22.50	51	14.96	172.80	3
	Raw Materials	447		4950	184	2767	0.15	389621.56	145
	Water	1519		1048	395	412	4.99	4757.22	13
	Total Provision	3741		14,337	946	5,726			462
Regulation	Air Quality Regulation			421	33	224	0.10	2093.82	10
	Biological Control								
	Climate Regulation	81		17,099	220	14,682	0.03	880238.73	60
	Erosion Prevention	4904		4892	951	2,134	4.83	47631.17	28
	Regulation of water flows			1.57	1.57	1.23	0.34	2.80	2
	Gas Regulation								
	Moderation of extreme events	6679		14,089	811	6,895	0.34	263808.54	46
Waste treatment	202,369		3,711	1,288	994	1.36	27827.36	38	
	Total Regulation	214,034		40,214	3,304	24,931			184
Maintenance & Support	Maintenance of genetic diversity			5605	2442	3751	23.14	46613.13	12
	Maintenance of life cycles			2751	1739	1226	9.85	24199.67	19
	Habitat/Refugia	8101							
	Soil Formation								
	Maintenance of soil fertility			822	525	336	29.48	2580.02	7
	Total Maintenance & Support	8101		9178	4706	5313			38
Culture	Opportunities for recreation and tourism	2737		4890	238	2012	0.00	199993.67	106
	Aesthetic information			6312	490	5704	0.04	120,357	21
	Existence, bequest values			11083	301	6775	0.22	126366.27	21
	Information for cognitive development			1099	1488	219	4.90	3037.82	15
	Inspiration for culture, art and design			648	0.09	648	0.09	3889.54	6
	Spiritual experience			4	4		3.70	3.70	1
	Total Culture	2737		24,036	2521	15358			170
	Total	228,613	15,182	87,766	11,477	51,328			854

