Overview of Ecosystem Service: Blue Carbon Storage and Sequestration (Coastal Ecosystems)

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This section outlines how we value blue carbon storage and sequestration as an ecosystem service within the GEP framework. The analysis focuses specifically on carbon storage and sequestration provided by coastal and marine ecosystems. Analogous to terrestrial carbon, we quantify the carbon storage and sequestration capacities of these ecosystems to capture their contribution to mitigating atmospheric greenhouse gas concentrations and, consequently, their role in global climate regulation.

Coastal blue carbon refers to the carbon sequestered and stored within coastal ecosystems. Consistent with the existing literature, this study concentrates on three principal coastal ecosystems: mangroves, salt marshes, and seagrass meadows.

Carbon sequestration

Estimating Quantity

We follow the methodology outlined in Bertram et al. (2021) to quantify global blue carbon sequestration from mangroves, salt marshes, and seagrass meadows. Specifically, we estimate carbon sequestration by combining the spatial extent of each coastal ecosystem within a country's exclusive economic zone (EEZ) with corresponding ecosystem-specific annual carbon sequestration rates. For mangroves, we utilize the Global Mangrove Watch (GMW) Version 3.0 dataset (1996–2020), which offers high-resolution (12m), accurate, and comprehensive global data on mangrove extent. To map the spatial distribution of salt marshes, we use a global 30 m resolution annual wetland dataset developed by Zhang et al. (2024), which features a fine-grained classification system suitable for identifying coastal wetland types. For seagrass meadows, we rely on the Global Distribution of Seagrasses dataset (UNEP-WCMC, 2021), which provides comprehensive and standardized spatial data on seagrass extent. We adopt the estimated annual carbon sequestration rates across all countries from Bertram et al. (2021), with mean $\pm$ s.e. values of 1.74 ± 0.23 (Alongi 2014), 2.45 ± 0.26 (Ouyang and Lee 2014), and 1.38 ± 0.38 (Short et al. 2011) $\mathrm{MgC\,yr^{-1}\,ha^{-1}}$ for mangroves, salt marshes, and seagrass meadows, respectively. Using the spatial extent of each ecosystem within a country's EEZ and the corresponding carbon sequestration rates, we calculate the annual carbon sequestration for each ecosystem. Summing across all ecosystems yields the total annual blue carbon sequestration. The calculation process is illustrated in Figure.

Estimating Price

We adopt a carbon price of $678.33 per metric ton of carbon (C), corresponding to the mean social cost of CO_2 estimated by Rennert et al. (2022). In this context, we assume that carbon stored in these coastal ecosystems remains permanently sequestered.

Carbon storage

Analogous to our approach for blue carbon sequestration, we quantify global blue carbon storage from mangroves, salt marshes, and seagrass meadows within each country's EEZ. We employ the same spatial datasets to estimate the extent of each coastal ecosystem. Rather than applying annual sequestration rates, we utilize global carbon storage density maps for mangroves and salt marshes, and an average storage density for seagrasses to calculate the spatial distribution of carbon storage.

For mangroves, we use a dataset on accumulated carbon storage from 2000 to 2020 at a 1 km resolution (Wang et al. 2025). For salt marshes, we rely on a global dataset of soil organic carbon covering the period from 2000 to 2019 (Maxwell et al. 2023). For seagrass meadows, we adopt the median carbon storage density estimated by Krause et al. (2025), which provides carbon stock values for both biomass and soil based on a comprehensive global database comprising over 2,700 seagrass soil cores.

Estimating Price

To estimate the value of carbon storage, we employed the rental social cost of carbon (SCC) (Parisa et al. 2022) as the pricing metric. Parisa et al. (2022) provides the theoretical rationale for quantifying the value of short-term carbon storage. Following this approach, and within the framework of Gross Ecosystem Product (GEP), we estimate the annual price of blue carbon storage as follows:

$$\text{Carbon Rental Rate} = P_C(t) - P_C(t+1)e^{-r} = P_C(t)\left(1 - e^{-r}\right)$$

where $P_C(t)$ denotes the social cost of carbon in year t, and λ represents net discount rate equal to the difference between the discount rate and the rate of growth of carbon prices. This formulation reflects the rental valuation approach, capturing the annualized benefit of temporarily storing one metric ton of CO2 for one year. This measure represents the annualized marginal damage cost of emitting an additional metric ton of CO2, thereby aligning our valuation approach with established climate policy frameworks and principles of intertemporal cost-benefit analysis. We adopt a carbon price of \$678.33 per metric ton of carbon (C), corresponding to the mean social cost of CO2 estimated by Rennert et al. (2022). This value is employed for $P_C(t)$, the carbon price at time t. Furthermore, a discount rate of 2% is applied, following the same source. Based on these parameters, the annual rental rate for carbon is estimated to be approximately \$13.43 (in 2020 US dollars) per metric ton of carbon. To express this value in constant 2019 dollars, we adjust for inflation using the GDP deflator for 2019, reported by the World Bank as 1.85 percent. Accordingly, the inflation-adjusted rental carbon price is computed as $\$13.43/1.0185$, yielding approximately \$13.19 (in 2019 US dollars).

Valuation

After estimating both the quantities and prices of blue carbon sequestration and storage, the economic value of carbon sequestration, is calculated as:

$$\mathrm{GEP}_{\text{blue carbon}} = \mathrm{Q}_i \cdot \mathrm{P}_i \cdot 1,$$

where Q_i represents the biophysical quantity of carbon either sequestered annually or stored cumulatively in costal blue carbon ecosystems, and P_i denotes the corresponding valuation—either the average SCC or the rental SCC. This formulation follows the GEP framework, which translates ecosystem service flows or stocks into monetary values.

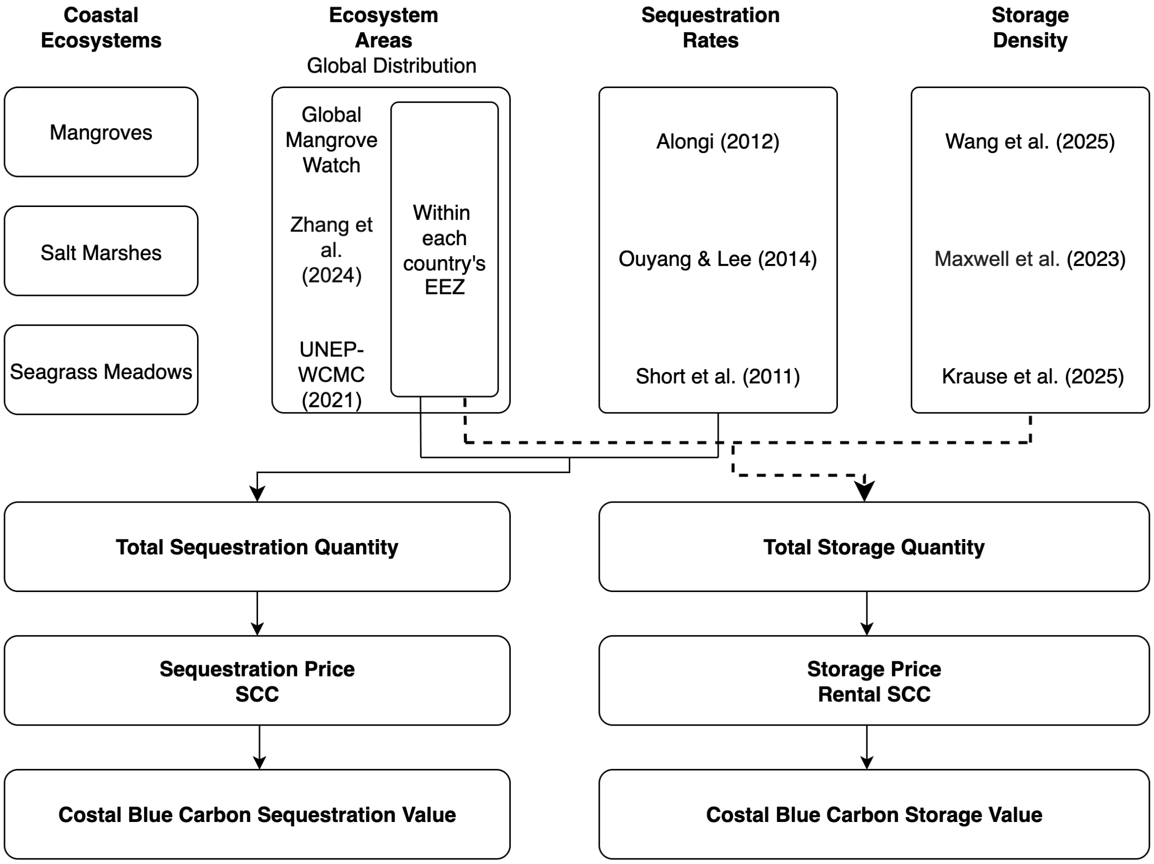

Figure 1: GEP valuation process for coastal blue carbon sequestration and storage.

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