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Role of carbonate burial in Blue Carbon budgets


Calcium carbonates (CaCO3) often accumulate in mangrove and seagrass sediments. As CaCO3 production emits CO2, there is concern that this may partially offset the role of Blue Carbon ecosystems as CO2 sinks through the burial of organic carbon (Corg). A global collection of data on inorganic carbon burial rates (Cinorg, 12% of CaCO3 mass) revealed global rates of 0.8 TgCinorg yr−1 and 15–62 TgCinorg yr−1 in mangrove and seagrass ecosystems, respectively. In seagrass, CaCO3 burial may correspond to an offset of 30% of the net CO2 sequestration. However, a mass balance assessment highlights that the Cinorg burial is mainly supported by inputs from adjacent ecosystems rather than by local calcification, and that Blue Carbon ecosystems are sites of net CaCO3 dissolution. Hence, CaCO3 burial in Blue Carbon ecosystems contribute to seabed elevation and therefore buffers sea-level rise, without undermining their role as CO2 sinks.
Mangrove forests and seagrass meadows have the capacity to elevate the seabed through the accretion of inorganic and organic particles at global rates of ~0.5 and ~0.2 cm yr\(^{-1}\), respectively\(^4\). Sediment accretion in mangrove forests and seagrass meadows leads to the sequestration of organic carbon (C\(_{\text{org}}\))\(^5\),\(^6\) originating from within and outside of the vegetated ecosystem\(^6\). Although mangroves and seagrass ecosystems occupy only a small fraction of the total coastal area (<2%), they contribute 10% and 25% to the yearly C\(_{\text{org}}\) sequestration in the coastal zone\(^6\), respectively. Recognition of mangrove and seagrass meadows, together with saltmarshes, as sites of intense C\(_{\text{org}}\) burial led to the formulation of Blue Carbon strategies to mitigate and adapt to climate change, through conservation and restoration of these ecosystems\(^7\)-\(^9\). The focus on Blue Carbon has provided substantial impetus to assess sediment C\(_{\text{org}}\) concentrations and burial rates in vegetated coastal ecosystems, which recently have been widely reviewed\(^9\).

C\(_{\text{org}}\) generally represents a minor fraction (2–3%) of buried material within mangrove and seagrass sediments\(^10\),\(^11\) (although this is highly variable\(^2\)), the rest being silicilastic and carbonate particles. A global assessment of the concentration of inorganic carbon concluded that C\(_{\text{inorg}}\) can exceed C\(_{\text{org}}\) concentration in seagrass sediments\(^13\). Seagrass and mangrove plants do not calcify per se; however, they provide habitats for an abundant associated calcifying fauna and flora (e.g., crabs, sea stars, snails, bivalves, calcified algae, foraminifera), whose shells and skeletons may be deposited and buried in the sediment along with the plant litter, and the organic and inorganic particles imported from adjacent ecosystems.

Counterintuitively, CaCO\(_3\) production represents a source of CO\(_2\) to the atmosphere, as calcification produces CO\(_2\) with a ratio of ~0.6 mol of CO\(_2\) emitted per mol of CaCO\(_3\) precipitated\(^14\). This has led to the argument that high CaCO\(_3\) burial may partially offset CO\(_2\) sequestration associated with C\(_{\text{org}}\) burial in some seagrass meadows and mangrove forests\(^15\). However, there are several caveats that affect these arguments and render inferences on the role of Blue Carbon ecosystems as net CO\(_2\) sinks or sources inconclusive\(^15\),\(^16\), based on the comparison of C\(_{\text{org}}\) and C\(_{\text{inorg}}\) sediment burial rates. To date, very few articles report the burial rates of CaCO\(_3\) in mangrove and seagrass ecosystems\(^15\)-\(^17\), and the role of CaCO\(_3\) burial in sediments and CO\(_2\) emissions depends on the balance between dissolution and production. If CaCO\(_3\) dissolution equals local calcification, then the burial of CaCO\(_3\) is supported exclusively by allochthonous inputs and is neutral in terms of CO\(_2\) emissions or sequestration. If dissolution exceeds local calcification, then CaCO\(_3\) dynamics add to the CO\(_2\) sink capacity of Blue Carbon ecosystems, even if CaCO\(_3\), which must be subsidized from allochthonous sources, is buried in the sediments. Only if CaCO\(_3\) dissolution is lower than local calcification does CaCO\(_3\) burial result in CO\(_2\) emissions.

Here we address the current gap in global estimates of C\(_{\text{inorg}}\) burial in seagrass and mangrove ecosystems by providing first estimates of contemporary (last century) C\(_{\text{inorg}}\) burial rates. We rely on a compilation and analysis of data on sediment chronologies (i.e., including radiometric dating of sediment cores with \(^{210}\)Pb) and C\(_{\text{inorg}}\) concentrations from around the world (Fig. 1). We compare burial, calcification and dissolution rates in three locations where most of the carbon mass balance terms were available. We then address the role of CaCO\(_3\) burial in CO\(_2\) emissions by resolving the source of the CaCO\(_3\) buried in seagrass meadows as either allochthonous or autochthonous (i.e., from associated flora and fauna). We conclude that the high amounts of CaCO\(_3\) found in Blue Carbon sediments cannot be converted into CO\(_2\) emissions.

Results

Global disparities in Blue Carbon sediments. CaCO\(_3\) supports an important part of sediment accretion rates (SARs) in seagrass ecosystems, although with large geographical disparities and a non-normal distribution (Shapiro–Wilk test, \(p < 0.001\)). Indeed, in 40% of global locations, the CaCO\(_3\) concentration was under 10% dry weight (DW), whereas in 28% of locations the CaCO\(_3\) content exceeded 80%DW (see Supplementary Figure 1a). Overall, the median (interquartile range: IQR) global concentration of CaCO\(_3\) in seagrass meadow sediments was 61 (56) %DW (mean ± SE of 54 ± 7).

In mangrove forests, we observe a large difference between the mean (± SE) and the median (IQR) CaCO\(_3\) concentration: 21 ± 11% and 3 (31)%, respectively. This is explained by the strong non-normal distribution between the eight study locations examined, including a group of five locations with < 5%DW CaCO\(_3\) in their sediments and three locations with CaCO\(_3\) contents between 20 and 75%DW (Shapiro–Wilk test, \(p < 0.001\), see Supplementary Fig. 1b). Converted into C\(_{\text{inorg}}\) concentrations (after normalization for the sediment bulk density), we obtain median (IQR) C\(_{\text{inorg}}\) concentrations in seagrass and mangrove sediments of 59 (66) and 1 (21) mgC\(_{\text{inorg}}\) cm\(^{-3}\), respectively (means ± SE of 63 ± 11 and 35 ± 17 mgC\(_{\text{inorg}}\) cm\(^{-3}\)) (Fig. 2a).

Using the median SARs in seagrass and mangrove ecosystems compiled in this study (0.22 and 0.23 cm yr\(^{-1}\), respectively; Fig. 2b), we estimate median (IQR) C\(_{\text{inorg}}\) burial rates in seagrass and mangrove ecosystems of 87 (154) and 6 (207) gC\(_{\text{inorg}}\) m\(^{-2}\) yr\(^{-1}\), respectively (means ± SE of 182 ± 94 and 90 ± 43 gC\(_{\text{inorg}}\) m\(^{-2}\) yr\(^{-1}\)) (Fig. 2c, Fig. 3). These values correspond to vertical accretion rates of CaCO\(_3\) of the order of 0.1 and 0.001 cm yr\(^{-1}\) in seagrass and mangrove ecosystems, respectively. Our median SARs agree with previously reported global values\(^13\). However, our new estimates of burial rates are lower than the previous, indirect median estimate of C\(_{\text{inorg}}\) burial rate of 108 gC\(_{\text{inorg}}\) m\(^{-2}\) yr\(^{-1}\) (mean ± SE of 126 ± 31 gC\(_{\text{inorg}}\) m\(^{-2}\) yr\(^{-1}\)) reported by Mazzarrasa et al.\(^13\).
Discussion

CaCO$_3$ burial in Blue Carbon ecosystems is the balance between inputs (autochthonous and allochthonous) and losses (dissolution and export). Assessments of the mass balance of CaCO$_3$ in seagrass meadows are few and none have been reported, to our knowledge, in mangrove forests. For seagrass ecosystems, we assessed the balance between calcification, dissolution and burial of CaCO$_3$ in three locations: the Balearic Islands, Spain $^{20,21}$, Shark Bay in Western Australia $^{22}$ and Florida Bay, USA $^{23,24}$ (Table 2).

The most comprehensive assessment of seagrass carbon budgets is that reported for a Mediterranean *Posidonia oceanica* meadow at Magalluf (Mallorca Island, Spain) $^{20,21,25,26}$. In this meadow, Barrón et al. $^{21}$ estimated a net CO$_2$ uptake by primary production of 8.4 gC m$^{-2}$ yr$^{-1}$. This estimate was corroborated by the C$_{org}$ burial rate, estimated independently, at 9 ± 2 gC$_{org}$ m$^{-2}$ yr$^{-1}$ $^{27}$. Barrón et al. $^{21}$ also estimated net calcification rates of 51 gCaCO$_3$ m$^{-2}$ yr$^{-1}$, corresponding to 6 gC$_{inorg}$ m$^{-2}$ yr$^{-1}$. This amount of calcification would result in a CO$_2$ emission of 3.6 gC m$^{-2}$ yr$^{-1}$ (0.6-fold the net calcification) $^{14}$. The CO$_2$ emission by calcification therefore represents an offset of 40% of the CO$_2$ uptake from net primary production (thereby yielding a total CO$_2$ sequestration of 4.8 gC m$^{-2}$ yr$^{-1}$ $^{21}$). However, the C$_{inorg}$ burial rate in this meadow is estimated here at 226 gC$_{inorg}$ m$^{-2}$ yr$^{-1}$. This is two orders of magnitude greater than the net calcification rate of 6 gC$_{inorg}$ m$^{-2}$ yr$^{-1}$ $^{21}$ (Table 2). This implies that about 90% of the CaCO$_3$ burial in this seagrass meadow must be supported by allochthonous inputs. Therefore, calculation of the CO$_2$ sequestration by comparing C$_{org}$ and C$_{inorg}$ burial rates or stocks would have concluded that this meadow is a strong source of CO$_2$ whereas estimates of calcification rates and net primary production concludes that it is a sink (as confirmed independently through air-sea flux measurements) $^{26}$.

Similarly, in Shark Bay, the burial of C$_{inorg}$ is four times higher than the independently reported net calcification rate $^{22}$ (Table 2). This again could require large allochthonous carbonate inputs.

In Florida Bay, the low ratio between C$_{org}$ and C$_{inorg}$ concentration in the sediment (g cm$^{-3}$) implied that seagrass meadows may be a net source of CO$_2$ to the atmosphere $^{15}$. However, such assessment requires consideration of the full carbon mass balance, including accounting for allochthonous inorganic carbon inputs and the balance between calcification and dissolution in the meadows. The contemporary C$_{inorg}$ burial rates in Florida Bay are approximately ninefold higher than the global median, whereas median SAR is about fourfold higher than estimated globally, in an area where 80% of the sediment dry mass is composed of CaCO$_3$. However, attempts to assess the gross or net calcification rates in the area yielded values one and two orders of magnitude lower than the estimated CaCO$_3$ burial rates (Table 2) $^{23,24}$. In contrast, past geological work in the Bay has suggested that it is a net producer of CaCO$_3$ $^{28}$. It is likely to be that some areas within this large Bay act as sources of CaCO$_3$ and some others as sinks, helping explain the discrepancy between reported production and burial estimates. Hence, internal redistribution of CaCO$_3$ production within Florida Bay needs to be considered when drawing inferences on the role of seagrass meadows from sediment composition.

These three example locations are in areas close to coral reefs and/or terrestrial lithogenic sources of CaCO$_3$. We could not find estimates of calcification rates (net or gross) in areas without external sources of CaCO$_3$. The discrepancies between calcification rates and burial rates in the three example locations could indicate that an important fraction of CaCO$_3$ burial (> 90%) is supported by CaCO$_3$ produced elsewhere and trapped in the seagrass sediments. This conclusion is consistent with
comparable Cinorg concentrations within and outside seagrass meadows, whereas, in contrast, Corg concentrations are higher in seagrass sediments\textsuperscript{13}. A large role of Cinorg import is also consistent with the large CaCO\textsubscript{3} export from coral reefs to adjacent waters, equivalent to 25–50\% of the CaCO\textsubscript{3} production, predominantly to reef lagoons\textsuperscript{27}, where seagrass meadows and mangroves often grow. Mangroves, seagrass and saltmarsh ecosystems are likely to be sites of net carbonate dissolution. Roots of marine plants release organic compounds and oxygenate the sediments during the day, promoting microbial aerobic remineralization of organic matter, thereby increasing sedimentary respiratory CO\textsubscript{2}\textsuperscript{28,30} and/or stimulating the re-oxidation of reduced metabolites. These processes result in the release of strong acids (e.g., H\textsubscript{2}SO\textsubscript{4}, HNO\textsubscript{3})\textsuperscript{31–33}, which leads to CaCO\textsubscript{3} dissolution in the sediment\textsuperscript{34,35} (although re-precipitation can occur\textsuperscript{34}).

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**Figure 2** Sediment cores data. a Inorganic carbon (C\textsubscript{inorg}) concentration, b sediment accumulation rates (SAR), and c Cinorg burial rates. The x represents the mean. Bars are the first and last quartile.

**Figure 3** Inorganic carbon burial rates in all locations. Mean Cinorg burial rates in all locations in sediment cores for seagrass meadows and mangrove forests, organized from low to high latitudes. Bars are the SE. Labels are the number of cores per location.

**Table 1** Median (mean) global Cinorg burial rates for seagrass meadows and mangrove forests considering one, and, for seagrass, two world regions (tropical and higher latitudes)

<table>
<thead>
<tr>
<th>Burial rate, (TgC\textsubscript{inorg} yr\textsuperscript{-1})</th>
<th>Global</th>
<th>Tropical</th>
<th>Higher lat.</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seagrass</td>
<td>This study</td>
<td>13(27)–52(109)</td>
<td>14(41)–57(163)</td>
<td>1(3)–5(14)</td>
</tr>
<tr>
<td></td>
<td>Mazarassa et al\textsuperscript{13}</td>
<td>19(28)–65(79)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mangrove</td>
<td>This study</td>
<td>0.8(12)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dissolution of CaCO₃ might also be influenced by the CO₂ system in the water column of Blue Carbon ecosystems. Respiration and photosynthesis of the flora and fauna, together with sediment redox processes in seagrass and mangrove ecosystems, strongly influence the chemistry of the water column, generating large diel amplitudes of the saturation state for CaCO₃ (Ω) with a tendency towards dissolution or the reduction of calcification at nighttime, amplified at low tide. The dissolution of allochthonous CaCO₃ in carbonate platform areas, caused directly or indirectly by metabolism of the marine vegetation and associated biota, leads to a reduction in pCO₂ through the release of dissolved total alkalinity. This sink of atmospheric CO₂ should be incorporated into the Blue Carbon framework. A recent assessment considers alkalinity addition through the dissolution of allochthonous carbonate as a very effective geo-engineering approach to remove atmospheric CO₂ and mitigate climate change.

Similarly, saltmarshes are not known to host high levels of calcifying organisms but can accumulate CaCO₃ from allochthonous sources. In arid tropical saltmarshes of the Western Arabian Gulf, dominated by succulent shrubs, a concentration of CaCO₃ of 57 ± 8% in sediments and a contemporary burial rate of 1% DW in the presence of both allochthonous sources was less than would be expected if these variables were additive. The presence/absence of coral reefs and lithogenic sources accounted for 36% of the variation in CaCO₃, whereas the random variables (study, lithology grouping and marine province) accounted for 54% of the variation in CaCO₃ (see Methods for model description). Mangrove sediment samples showed a similar pattern to the seagrass meadows and the presence of allochthonous sources had a marginally significant positive effect on the amount of CaCO₃ in the sediment (t-value = 4.29, df = 1.81, p = 0.0596). The presence/absence of a CaCO₃ source accounted for 71% of the variation of CaCO₃ within mangrove sediments, whereas the random variables accounted for 20% of the variation in CaCO₃.

In testing for biases of outlying cores and studies, we found that one study from Western Florida had an outlying data point that disproportionately skewed the results. The study from Western Florida had relatively low CaCO₃ but did have an allochthonous source of CaCO₃. When this study was removed from the analysis, the presence of an allochthonous source became significant (t-value = 7.92, df = 4.16, p = 0.0012). This highlights the need for more studies in mangrove sediments to determine the global influence of allochthonous sources on CaCO₃ content.

In seagrass meadows, the median (IQR) CaCO₃ burial rate found in areas where no allochthonous sources were identified was 1 (13) gCaCO₃ m⁻² yr⁻¹ (mean ± SE of 8 ± 4), only 1.1% of the global median. This contrast is consistent with our hypothesis that much of the CaCO₃ buried in seagrass and mangrove sediments is allochthonous. It explains the non-normal distribution of CaCO₃ concentrations observed in sediments of seagrass and mangroves (Supplementary Figure 1), and indicates that the import of CaCO₃ from carbonate-forming ecosystems or adjacent karstic areas is the norm.

The global burial rate of CaCO₃ in seagrass meadows is between a third to a half of their Corg burial rate. If the buried CaCO₃ and Corg in seagrass sediments were produced entirely in situ, Corg burial would offset up to a third of CO₂ sequestration through Corg burial, particularly in tropical seagrass ecosystems where ~90% of the global Corg burial occurs. However, imbalances between production, dissolution and burial, and the observation of much higher CaCO₃ concentrations in sediments near lithogenic formations and coral reefs, suggest that, where present, allochthonous CaCO₃ inputs are substantial and support most of the net CaCO₃ burial.

Locally, despite supporting significant CaCO₃ burial, Blue Carbon ecosystems may be sites where imported CaCO₃ dissolves, strengthening rather than weakening the capacity of these ecosystems to sequester CO₂. Whereas there is emphasis on apportioning the sources of autochthonous and allochthonous Corg in Blue Carbon sediments (up to 50% of the buried Corg), determining the sources of CaCO₃ in Blue Carbon sediments is just as important, to resolve the role of vegetated coastal

Table 2 Burial rates of CaCO₃ compared to calcification rates in seagrass ecosystems

<table>
<thead>
<tr>
<th>Sediment</th>
<th>Community production rate of CaCO₃</th>
<th>Community net calcification rate</th>
<th>Sediment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gCaCO₃ m⁻² yr⁻¹</td>
<td>gCinorg m⁻² yr⁻¹</td>
<td>gCaCO₃ m⁻² yr⁻¹</td>
</tr>
<tr>
<td>Florida Bay, USA</td>
<td>626±324</td>
<td>75</td>
<td>18±9</td>
</tr>
<tr>
<td>Balearic Islands, Spain</td>
<td>68±20</td>
<td>8</td>
<td>51±1</td>
</tr>
<tr>
<td>West Shark Bay, Australia</td>
<td>375±6222</td>
<td>45±7</td>
<td>295±22</td>
</tr>
</tbody>
</table>

Comparison between seagrass-associated community production rate of carbonate (obtained from standing stock assessments and leaves or calcification rates (balance between calcification and dissolution, calculated from variations of total alkalinity) from the literature, and carbonate burial rate in three locations with carbonate-rich sediments.
ecosystems as CO2 sinks and, hence, their potential to support climate change mitigation. The current focus on Corg budgets in vegetated coastal ecosystems needs to be augmented with integrative assessments of organic and inorganic carbon fluxes and budgets, including both allochthonous and autochthonous inputs. Moreover, these assessments must consider the sources and fate of carbon exchanged between Blue Carbon and adjacent ecosystems, as Blue Carbon ecosystems export important amounts of their organic production but also import significant amounts of CaCO3 and organic matter from adjacent sources. A comparison of paired vegetated and unvegetated sediment CaCO3 %DW showed that vegetated and adjacent unvegetated sediments have similar carbonate concentrations, both using standard parametric statistics (general linear model (GLM), t-value = 1.32, df = 83.1, p = 0.191) and meta-analysis (z-value = 0.88, p = 0.379; Supplementary Fig. 2A,B), which also showed no evidence for reporting bias (all points within the 95% confidence lines of the funnel plot, Supplementary Fig. 2C). This provides further support to the hypothesis that much of the carbonate buried in vegetated coastal sediments derives from allochthonous sources rather than being produced within the habitat.

Inorganic carbon burial in Blue Carbon ecosystems has been overlooked, with the rates compiled here representing the first direct estimates reported in the literature. These estimates confirm that seagrass ecosystems, and to lesser extent mangrove ecosystems, are intense sites of CaCO3 burial, supporting sediment accretion. CaCO3 burial is a fundamental process supporting the role of Blue Carbon ecosystems in climate change adaptation, which is underpinned by their capacity to rapidly accrete sediments, reducing relative SLR by raising the seafloor.

**Methods**

**Calculation of the C<sub>inorg</sub> accretion rate.** We searched the peer-reviewed literature for data on sediment cores dated with 210Pb, including CaCO3 or C<sub>inorg</sub> concentration in seagrass and mangrove sediments. Search terms on Google Scholar were seagrass OR mangrove AND 210Pb OR SAR OR sediment accretion rate. We then searched returned articles that contained data on SAR and CaCO3 or C<sub>inorg</sub> data. We found only one study presenting CaCO3 content in a dated sediment core. However, we found 15 and 22 studies with SAR for seagrass and mangrove sediments, respectively. To obtain the CaCO3 or C<sub>inorg</sub> concentrations needed to calculate C<sub>inorg</sub> burial rates, we used the database of Mazarrasa et al.13, which was the most recent exhaustive compilation of sediment cores from Blue Carbon habitats, for data on CaCO3 in seagrass sediments. We also contacted experts in Blue Carbon studies (published studies using cores from Blue Carbon habitats) for unpublished CaCO3 sediment concentration data (see data and references in Supplementary Data 1). In total, we compiled 42 and 53 210Pb dated cores with CaCO3 content in mangrove and seagrass ecosystems, respectively (see PRISMA checklist and flow diagram in Supplementary Note 1).

The SARs (cm yr<sup>-1</sup>) from the literature were re-calculated according to the constant flux–constant sedimentation model<sup>38</sup>, to have a coherent and comparable dating system between all cores. The CaCO3 concentration (% sediment DW) was calculated as the mean between all slices younger than 1900, for cores with the contemporary 210Pb chronologies. The C<sub>inorg</sub> concentration in sediment (gC<sub>inorg</sub> m<sup>-3</sup>) was calculated from the dry bulk density (g m<sup>-3</sup>) and the percentage of CaCO3 content (using sediment DW), considering a mass ratio of 12% carbon in CaCO3. The C<sub>inorg</sub> burial rate (gC<sub>inorg</sub> m<sup>-2</sup> yr<sup>-1</sup>) was then calculated as the product of the SAR and the C<sub>inorg</sub> concentration for each sediment core. Cores with negligible content of CaCO3 were also included in the calculation (see Supplementary Figure 1).

All cores from the same site or area and with similar presence or absence of allochthonous sources of CaCO3 (see below) were treated as replicates for a global location and averaged for the analysis (geologic grouping). For seagrass, the 51 cores dated with 210Pb were grouped into 17 locations (Figs. 2, 3). For mangroves, we compiled a total of 42 cores dated with 210Pb in 8 locations (Figs. 2, 3). Seagrass locations ranged from tropical to sub-arctic locations, with 50% of estimates derived from tropical and subtropical locations and 50% from higher latitudes. Mangrove sediment derived mostly from subtropical locations (seven out of eight locations), particularly in Australia and the Arabian Peninsula (Supplementary Figure 2).

**Determination of the influence of allochthonous sources of CaCO3.** We analysed the influence of the presence/absence of coral reefs and continental shelf lithology (qualitative data), as potential allochthonous sources of CaCO3 in seagrass and mangrove sediments (in %DW) (see dataset in Supplementary Data 1). For seagrass, we expanded our dataset by including CaCO3 concentrations from 264 cores compiled by Mazarrasa et al.<sup>13</sup>, reaching a total of 341 cores with measured CaCO3 %DW.

We estimated the presence/absence of coral reefs using the map of the global distribution of warm-water coral reefs compiled by the UNEP-WCMC<sup>20</sup> and the presence/absence of nearby lithogenic sources using the global lithology map of Hartmann and Moosdorf<sup>21</sup> and the world soil map of the FAO/UNESCO (http://www.fao.org/soils-portal/en/). The coring locations were associated with climate regions following the Köppen–Geiger classification system<sup>22</sup>.

**Statistical analysis.** All data distributions were tested for normality to determine the most reliable central tendency measured with Shapiro–Wilks normality test (Statistica, Dell Software). None of the datasets of SAR, C<sub>inorg</sub> concentration, C<sub>inorg</sub>
burial rate or CaCO3 %DW were normally distributed (all \( p < 0.05 \)). We therefore chose to use the median (IQR) as the most appropriate description of central tendency. Traditional meta-analysis tools, which calculate effect sizes to standardize the difference between control and experimental treatments, thereby allowing comparison among disparate response variables and weighting to account for unequal variance among studies, could not be used for this analysis for multiple reasons. These reasons include that the question posed and the studies available did not include experimental designs with paired control and experimental plots required for effect size calculations, that there was a single response variable facilitating direct comparison and data integration, and, most importantly, that we used the raw data for each core. Instead, we ran a statistical test using a mixed effect GLM to determine the difference between control and experimental treatments, thereby allowing for the data structure and minimize non-independence, we calculated the global median Cinorg burial rates and the estimated global seagrass area, which ranges from 150,000 to 600,000 km². We also calculated the global annual burial rate of inorganic carbon (\( Tg_{\text{Cinorg} \ year^{-1}} \)) in seagrass meadows as calculated at the product of the global median Cinorg burial rates and the estimated global seagrass area, which ranges from 150,000 to 600,000 km². We also calculated the global annual burial of Cinorg as the sum of separate calculations for tropical and arid climates and meadows at higher latitude climates. Median Cinorg burial rates were calculated for tropical (core locations with tropical and hot desert climates) and non-tropical areas (temperate, continental and polar climates) and multiplied by the global seagrass cover range under the assumption that 2/3 of the seagrass area is in the tropical and subtropical zone. The global annual burial of inorganic carbon (\( Tg_{\text{Cinorg} \ year^{-1}} \)) in mangroves was calculated as the product of the global median Cinorg burial rates and the estimated global mangrove cover of 137,760 km².

### Data availability

The dataset is available as Supplementary Data 1.

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### Calculation of global yearly burial rates of Cinorg

The global annual burial of inorganic carbon (\( Tg_{\text{Cinorg} \ year^{-1}} \)) in seagrass meadows was calculated as the product of the global median Cinorg burial rates and the estimated global seagrass area, which ranges from 150,000 to 600,000 km². We also calculated the global annual burial of Cinorg as the sum of separate calculations for tropical and arid climates and meadows at higher latitude climates. Median Cinorg burial rates were calculated for tropical (core locations with tropical and hot desert climates) and non-tropical areas (temperate, continental and polar climates) and multiplied by the global seagrass cover range under the assumption that 2/3 of the seagrass area is in the tropical and subtropical zone. The global annual burial of inorganic carbon (\( Tg_{\text{Cinorg} \ year^{-1}} \)) in mangroves was calculated as the product of the global median Cinorg burial rates and the estimated global mangrove cover of 137,760 km².

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Author contributions
