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Conversion Carbon Capture and Storage Factors in Temperate Human Controlled Wetland

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Abstract: This paper provides guidance for the quantification and reporting of blue carbon removals in the temperate coastal ecosystems, “Italian valli da pesca” or H.C.W. (Human Controlled Wetland, Lat. 45° Lon. 12°), where some pools as seagrasses, and salt marshes, are highly efficient at capturing and storing carbon dioxide (CO_2) from the atmosphere. Halophyte salt marsh plants were found to have a %C on Dry Weight (D.W.) of 32.26 ± 3.91 (mean ± standard deviation), macrophytes 33.65 ± 7.99, seagrasses 29.23 ± 2.23, tamarisk 48.42 ± 2.80, while the first 5 centimetres of wetland mud, on average, had a %C of 8.56 ± 0.94. Like the ISO (International Organization for Standardization) 14064 guideline to quantify the GHG (Greenhouse Gas) emission, we have studied the different conversion factors to be used as a practical tool for measurement the CO_2 sink activity. These factors are essential to calculate the overall carbon reduction in a project located in temperate wetland using a method as the ISO 14064.2, UNI-BNeutral, VCS VERRA or other that will come.

Key words: Blue carbon, carbon conversion factor, Carbon Capture and Storage, CO_2, UNI BNeutral, VERRA VCS, wetland.

1. Introduction

Coastal ecosystems, particularly mangroves, seagrasses, and salt marshes, are highly efficient at capturing and storing carbon dioxide (CO_2) from the atmosphere. They sequester carbon at rates that can be several times higher than terrestrial forests. By protecting and restoring these ecosystems, we can effectively reduce the concentration of CO_2 in the atmosphere, which is crucial for mitigating climate change. The Italian “valli da pesca” (Fig. 1) are temperate H.C.W. (human controlled wetland) areas [1, 2].

By 2010 many organizations are involved in projects to generate “blue carbon” from these temperate areas and provide a means to conserve and restore coastal ecosystems, sequester carbon, support biodiversity, protect coastal communities, and offer economic benefits, all while contributing to global climate change mitigation efforts. The ISO (International Organization for Standardization) 14064-1 standard, in particular, provides guidance on the principles and requirements for the quantification and reporting of GHG (Greenhouse Gas) emissions and removals at the organizational level. It includes guidelines on the use of conversion factors, which are used to convert activity data (e.g., energy use, fuel consumption) into GHG emissions or removals.

Conversion factors typically cover various GHG (e.g., carbon dioxide, methane, nitrous oxide) and may be expressed in terms of carbon dioxide equivalent (CO_2e) to provide a common unit of measurement for different gases. These factors are essential to calculate the overall carbon footprint of an organization or a specific activity. The same way, we can calculate the carbon stock in temperate wetlands. It depends on factors such as wetland type, location, size, and environmental conditions. Carbon stock refers to the amount of carbon stored in a particular ecosystem, including both living and dead organic matter. Wetlands, including temperate wetlands, can be significant carbon sinks, which means

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Fig. 1 The Italian H.W.C. "Valli da pesca".

they store more carbon than they release into the atmosphere.

There are some components (pool) of carbon stock in temperate wetlands:

(1) Soil Organic Carbon

Wetland soils are often rich in organic carbon. The waterlogged conditions in wetlands slow down the decomposition of plant material, leading to the accumulation of organic matter in the soil. This organic carbon can be stored for long periods, making wetland soils important carbon reservoirs.

(2) Vegetation

The type and density of vegetation in temperate wetlands play a crucial role in carbon storage. Marshes, swamps, and bogs may have different types of vegetation, and some plants, like cattails and sedges, are known for their high carbon content. The biomass of wetland vegetation contributes to the carbon stock.

(3) Peat Formation

In some temperate wetlands, particularly bogs and fens, peat can accumulate over thousands of years. Peat is composed of partially decomposed organic material, primarily sphagnum mosses, and it can store a significant amount of carbon. These peatlands are often referred to as "carbon banks".

Table 1 Wetland carbon pool used by the PdR UNI 99:2021.

Algal biomass
Seagrass biomass
Below water mud biomass
Salt marsh biomass
Halophytic salt marsh plants
Halophytic tree "Tamarix sp."

The H.C.W. "Italian valli da pesca" preserves these pools by the waterlogged conditions that limit the decomposition of organic matter by microbes, and preserves carbon in the form of peat and soil organic matter. In opposition of the wild wetland, the Human Controlled "valli da pesca" prevents (1) the drainage or hydrology alterations that can release the stored carbon into the atmosphere and (2) human activities, such as land development, drainage for agriculture, and peat extraction. When wetlands are drained or disturbed, carbon can be released into the atmosphere, contributing to GHG emissions. Conservation and restoration efforts, commonly performed in "valli da pesca" protect these ecosystems and their carbon stocks, which can help mitigate climate change by keeping carbon out of the atmosphere.

The UNI-BNeutral method [3] and the VERRA-VCS (https://verra.org/registry) give us an estimation approach and some wetland carbon pools as described in Table 1. This paper describes the most current and region-specific conversion factors for a CO_2 pool. It can be used to simplify the GHG sink calculations in the temperate wetland [4].

2. Materials and Methods

According to the Doimi and Minetto [5], sampling took place in three H.C.W. located in three different areas: valle Zignago (Fig. 2) Lat. 45.688326 Long. 12.888266, 660 ha (80% water); val Dogà (Fig. 3) Lat. 45.558261 Long. 12.536424, 1,650 ha (60% water); and valle A.M.A (Fig. 4) Lat. 45.349900 Long. 12.156709, 300 ha (80% water) [6], that represent high, medium and low carbon sink activity.

Sampling was done in three different "seasons": winter 4-8 ℃ air temperature, intermediate 8-18 ℃ and summer > 18 ℃ [7, 8].

Fig. 2 The H.W.C. called "Val Zignago" with low carbon sink activity.

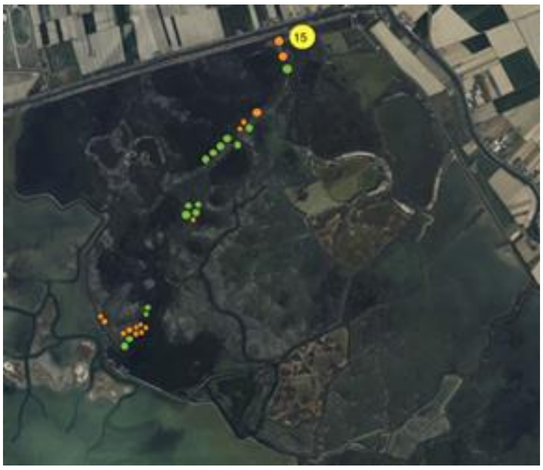

Fig. 3 The H.C.W. called "Val Dogà" with high carbon sink activity and the sample points.

Fig. 4 The H.C.W. called "Valle AMA" with medium carbon sink activity.

Each sampling activity was preceded by a preliminary analysis using Sentinel (Copernicus-ESA EU) satellite, which browsed a script to highlight aquatic plants and algae in lakes and lagoons (Aquatic Plants and Algae Custom Script Detector (APA Script, 2021). We selected homogeneous algal growth areas where the collection of samples of seagrasses + submerged salt marsh vegetation + below water mud sediment and salt marsh soil was done. In addition, random points per "valle" were identified for the tree plants sampling (Tamarix sp.).

To determine the seagrass biomass, a 50 × 50 cm quadrat was thrown into the lagoon water and the first 5 cm of sediment was also taken by coring [9].

Sample of the halophytic salt marsh plants, was done by the same procedure.

For the above ground tree plant Tamarix sp. we collect stem, branch and twigs (with or without foliage) to have a representative sample of the tree [10]. The species identification was carried out following the Sfriso identification keys [11] and the *Guida pratica per il riconoscimento delle fanerogame e per le azioni di trapianto* by LIFE SeResto.

Salinity, water temperature, air temperature, Total Dissolved Solids (T.D: S.) and water pH were also kept by using a special adapted boat-drone (www.ded-consulting.eu) equipped by a spectrophotometer, conductivity meter, water and air thermometer, pH meter, and T.D.S. probe (Fig. 5).

Each sample was classified, weighed and dried to 48 h at 65 ℃ re-weighed and pulverized.

Each sample was used to determine the TC (Total Carbon %) to be used as conversion factor by carbon pool biomass. The samples were processed for TC g/100g dm (1) by a custom and portable CO_2 laser analyzer [12] based on a study by Bernard et al. [13]; (2) and the value confirmed by an analysis using the UNI EN 13137:2002 methodology performed by the Depuraque Lecher laboratory (https://lecher.it), Salzano, Venice Italy.

Fig. 5 Radio controlled water drone equipped with probe and a spectrophotometer.

These analyses are correlated by the soil residue at 105 ℃ (%) by the methodology DM 13/09/1999 SO n° 185 GU n°248 21/10/1999 Met II.2, the CSC (Cation Exchange Capacity) expressed as meq/100g dm by the method DM 13/09/1999 SO n° 185 GU n° 248 21/10/1999 Met XIII.2 and bulk density kg/LT by ASTM D5057-10 method.

3. Results

Almost 80% of the Italian H.C.W. are under a cloud system environmental control (https://www.ded-consulting.eu/datalogger).

There is a correlation between seasonality and the carbon pool [1] (Figs. 6-8). The maximum carbon capture occurs on summer and is related to the GPP (Gross Primary Production) and EVI (Enhanced Vegetable Index). These parameters are easily controlled using the NASA Global Subsets Tool MODIS/VIIRS Land satellite control (https://modis.ornl.gov/globalsubset/).

A number of 135 samples of halophytes plants, 40 macroalgae and 51 seagrasses, 135 of mud and 9 of Tamarix sp. for a total of 370 samples divided on the different H.C.W were analyzed for % of TC.

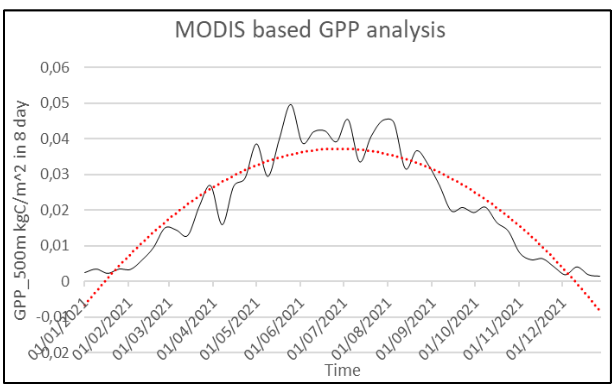

Fig. 6 H.C. wetland gross primary production.

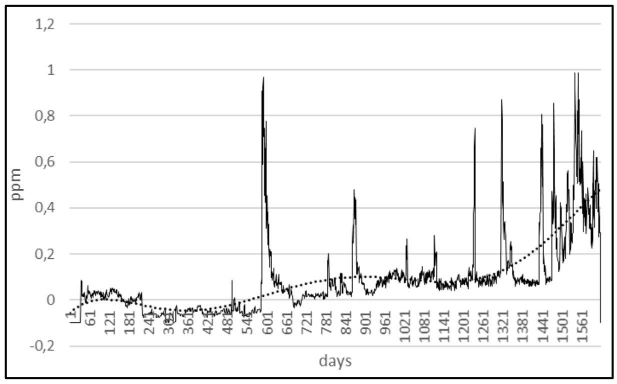

Fig. 7 Dissolved CO_2 into wetland water.

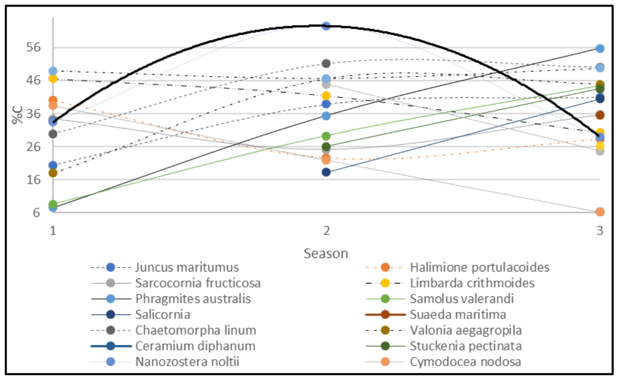

Fig. 8 Above ground halophytic shrubs pool %C per DW fluctuation with seasonality; with 1 = winter, 2 = intermediate, 3 = summer.

The Black Line Represents the Interpolation of all items.

3.1 Algae and Seagrass Carbon Pool

The H.C.W. seagrass *Ruppia maritima* reveals the mean value of 30.95% C. *Cymodocea nodosa* has a TC of 27.54%, *Najas mayor* to 31.39%, *Nanozostera noltii* 26.26%. This result is in the same range demonstrated by other author [14, 15].

About macroalgae, the most common, *Chaetomorpha linum*, has an average carbon content of 39.83%, which is only slightly different from the carbon content analyzed by Lenzi et al. [16], which indicated a range from 19.07% to 38.43%. On average, the macroalgae studied have a carbon content of 33.65% ±7.99% while seagrass have 29.23% ±2.23% (mean ±SD) (Fig. 9).

3.2 Halophytic Plants (Shrubs) Carbon Pool

The result varies among plants, from 28.98% for *Halimione portulacoides* to 40.42% for *Limbarda chrithmoides*, this is similar to other authors where the

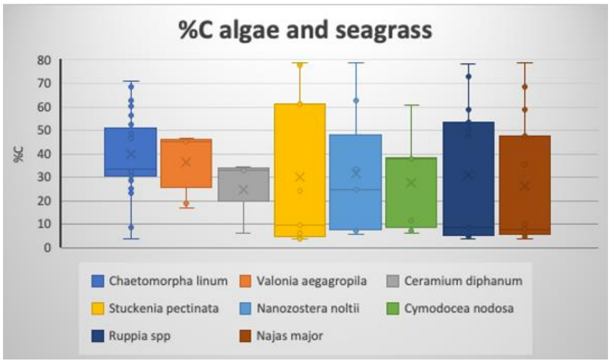

Fig. 9 Carbon content in H.C.W. algae and seagrass.

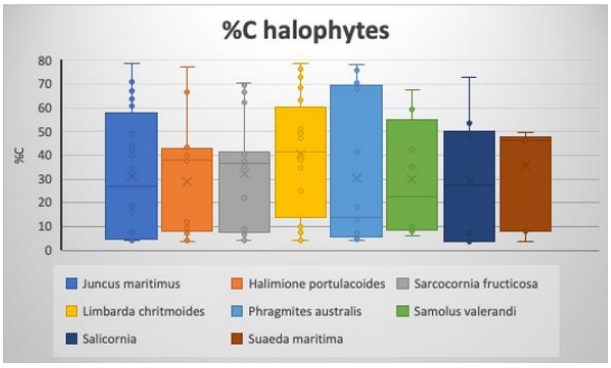

Fig. 10 Carbon content in H.C.W. halophytes.

carbon content varies between 24.39% and 39.6% [17]. On average, the halophyte plants studied have a carbon content on dry matter of 32.26% ±3.91% (mean ±SD) (Fig. 10).

3.3 Below Water Mud Sediment Carbon Pool

This carbon pool in the Temperate H.C. Wetland is to be considered as deltaic fluidized muds and it is subjected to deepening. The specific density changes from 0.8-1.5 kg/lt. Density lower to 1.5 kg/lt helps the deepening and can be considered as "fossorial" in opposition to the "geological" not fossorial, like the salt marsh barren (Fig.11).

Following Ref. [18] we can determine the carbon stock in the first 5 centimeters of the H.C.W. downstream sediment %C 8.56 ±0.94.

3.4 Above Water Salt Marsh Carbon Pool

In this case, the salt marsh is stable and no fluidized.

The carbon content is not subjected to deepening and this pool can be considered "geological".

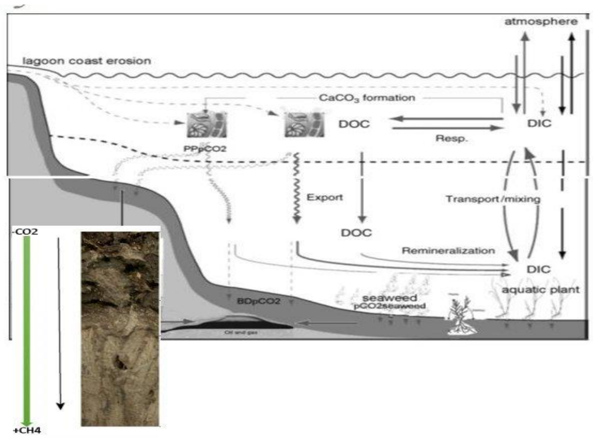

Fig. 11 Carbon cycle on fluidized muds and its deepening carbon flux in wetland lagoon by USA NOOA (2010); modified by D&D consulting; DIC (dissolved inorganic carbon); DOC (dissolved organic carbon) and pCO_2 seaweed (seaweed carbon storage)

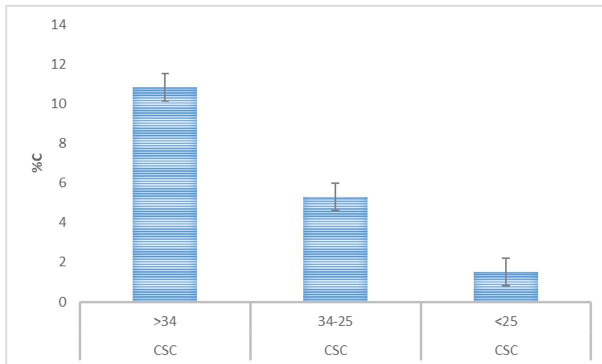

Fig. 12 The %C carbon content change from 2% to 11% ±0.64% (mean ±SD).

However, the %C is related to the CSC as indicated in the follow figure (Fig. 12).

3.5 Above Ground Tree Carbon Pool

The Tamarix sp. is a representative tree in the Italian H.C.W. It has an average total carbon content per dry matter of 48.42%. This result is compliant with Thomas and Martin [19].

4. Conclusion

The use of a default factor to determine the carbon sink in the H.C.W. temperate environment may be necessary in some situations due to practical constraints, data availability, and the need for standardized or simplified calculations. Here are a few reasons why default factors are suggested:

(1) Lack of Data: In many cases, detailed, site-specific data on carbon sequestration rates or emissions from different land uses or land management practices may not be readily available. Default factors provide a simple and consistent way to estimate carbon fluxes when specific data are lacking.

(2) Standardization: Default factors can help standardize carbon accounting and reporting. This is particularly important for international agreements like the Kyoto Protocol and the Paris Agreement, where countries need to report their emissions and removals in a consistent and comparable manner. Standardized defaults ensure that calculations are based on a common methodology.

(3) Simplicity: Default factors are often used to simplify calculations, especially for non-experts. For example, if you want to estimate the carbon sequestration in a forest, using a default factor based on the forest type can be much simpler than conducting detailed carbon measurements on each individual forest.

(4) Rapid Assessment: In some cases, quick estimates of carbon stocks or fluxes are needed for decision-making or reporting purposes. Default factors allow for these rapid assessments without the need for extensive data collection and analysis.

(5) Risk Management: Using default factors can also be a conservative approach when dealing with uncertainty. They often err on the side of caution, assuming lower sequestration rates or higher emissions, which can help account for any underestimations or unforeseen changes.

It is important to note that default factors are typically used as an estimation. They serve as a pragmatic solution to a technician or certification body auditor, to mathematically calculate the GHG sink (or removal) in the temperate H.C.W. “valli da pesca”. A high standard deviation is expected because there is a geographic and ecological difference of each H.C.W. Using an A.I. (Artificial Intelligence) model [5] we can classify the wetland carbon capture and storage activity into three groups (Fig. 13).

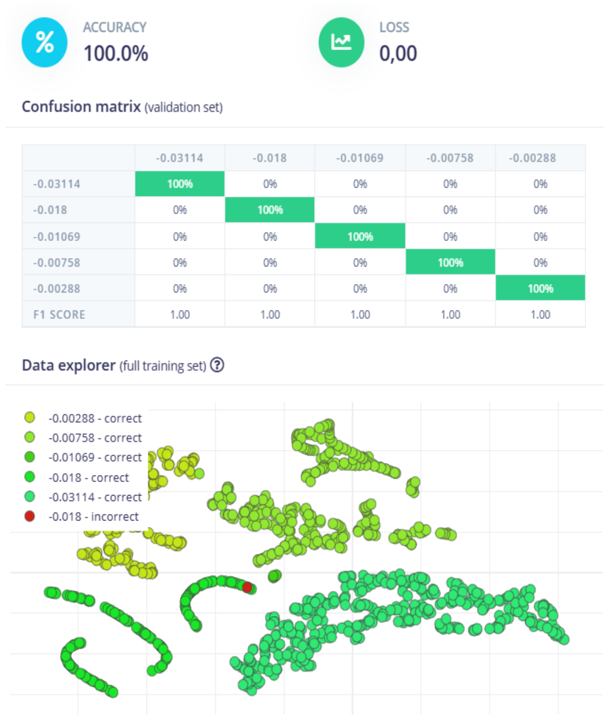

Fig. 13 H.C.W. carbon sink classification (TC^{m2}).
The first group is classified with high CCS activity (-0.018 to -0.03114) kg CO_2/m^2/year (dark green).
The second demonstrates an intermediate CCS activity (-0.01069) kg CO_2/m^2/year (light green).
The last is with a very low CCS activity (-0.00758 to 0.00288) kg CO_2/m^2/year (lighter green).
Logically, for each group, the carbon pools change and increase the standard deviation.

Other problem is the season variability of carbon contents of the pools [31]. More data would have been needed to understand the fluctuation over the seasons in %C on DW. The same applies to understand the fluctuation in %DW, although already with the results of this study, a trend can be seen. Using the satellite image analysis, we can easily estimate the carbon stock [20-22] that provides an estimate of the abundance of different vegetation types. Satellite imagery provided by Planet Labs PBC, CC BY-NC-SA 2.0 and Aquatic Plants and Algae Custom Script Detector (APA Script) [23] is a tool for estimation. In the temperate H, C.W., there are different pools for the Carbon Capture and Storage activity (Fig. 14) with different total carbon factors % (Table 2).

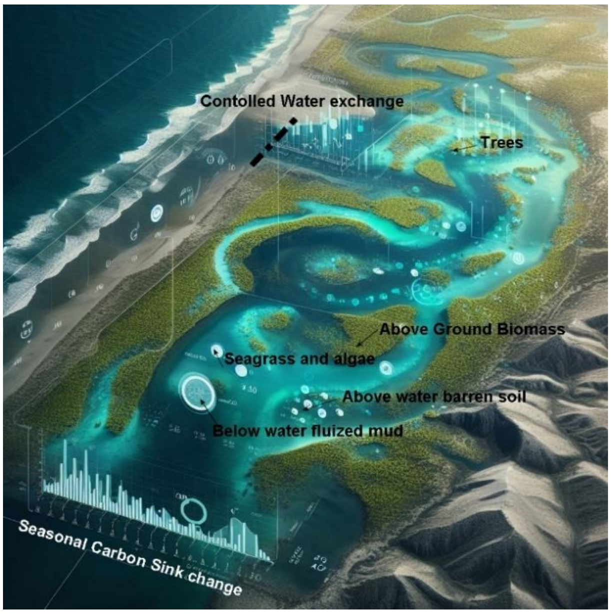

Fig. 14 The carbon sink pool in a temperate H.C.W. Italian named "valle da pesca".

Table 2 Total carbon factor (%) on different H.C.W. pool.

Carbon sink pool	Factor	Unit
AGB (halophytic plants)	32.26	TC %
Algae and seagrass	33.65	TC %
Below water mud sediment	8.56	TC %
Above water salt marsh	2-11	TC %
Above ground tree	48.42	TC %

Like VERRA VCS methodology [24], the calculation approach, using the value provided above is:

$$Ton\ GHG\text{-}_{factor\text{-}CO2} = [(factor/100)x\ ha \times 44/12]$$

To calculate the carbon stock of trees in the H.C.W., we have used the tamarisk plant as index. In this case, the allometric equations [25] and other, could be used to calculate the total biomass and carbon stock of this pool. The technician needs to identify the DBH (Diameter at Brest Height) or BA (Basal Area) of the Tamarix multiply for the carbon content per dry matter 48.42%.

$$Ton\ GHG\text{-}_{AGB\ tree\text{-}CO2,} = \{[(factor/100) \times (0.716+0.136\times BA) \times 44/12] \times tree\ number\}$$

The carbon dioxide content in the first 5 centimeters of the below water mud in the H.C.W. is where algae and aquatic plants that die during the winter and organic substances in general are deposited [4]. It is the most variable layer, as it is subject to biomass degradation [26-30]. Verra VCS said, according to his methodology VM0033, "soil organic carbon may be estimated by determining the organic carbon accumulated above a consistent reference plane and then dividing by the years since the date of the reference plane (for the baseline scenario) or the start of project activities (for the project scenario)."

In any case below-ground mud structures, including roots and rhizomes, particulate inorganic carbon and particulate organic carbon can persist for a long time and contribute to carbon sequestration, helping to remove carbon from the active carbon cycle. So it is important, for a blue carbon project, to include this important pool.

Likewise, the first layer of salt marsh barren soil is also an important carbon pool to calculate because it contains the below biomass halophytic salt marsh plants, and the tamarisk vegetation.

These plants store carbon not only in their above-ground biomass but also in their below-ground structures, including roots and rhizomes. These below-ground carbon-rich structures can persist for a long time and contribute to carbon sequestration, helping to remove carbon from the active carbon cycle.

In this case, the carbon content (% T.C.) is related to the CSC and it changes from each H.C.W, the first with high CSC activity (> 35) with a % T.C. of 10.83, the second with a medium CSC activity (34-25) with a % T.C. of 5.3 and finally the low CSC activity (< 25) with a % T.C. of 1.51. It is important to consider this in relation to the calculation of the carbon sink activity in the barren soil.

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