

Blue Carbon PH: An R-based web platform for databasing and computing blue carbon in the Philippines

Russel Christine B. Corcino*^{1,2} and Severino III G. Salmo¹

¹Institute of Biology, College of Science, University of the Philippines Diliman, Quezon City, 1101 Philippines

²Department of Biology, College of Computing, Artificial Intelligence and Sciences, Cebu Normal University, Cebu City, Cebu, 6000 Philippines

ABSTRACT

Blue carbon ecosystems (BCEs) such as mangrove forests and seagrass beds significantly contribute to climate change adaptation and mitigation. They are important carbon sinks, storing >50% of the ocean's sediment carbon stock. Effective BCE conservation requires accessible, accurate, and sufficient blue carbon stock (BCS) data. In the Philippines, a country known for high BCE cover, BCS data continues to increase but consolidation efforts are limited. We present *Blue Carbon PH*, a R-based online data analytic platform (DAP) for collating, computing and sharing BCS data in the country. It has three modules to compute BCS from either environmental data (using Module 1 - Compute Total Carbon Stock from Environmental Data) or mangrove vegetation data (using Module 2 - Compute Biomass Carbon Stock from Raw Data), and share BCS values from published or unpublished studies (using Module 3 - Upload Existing Carbon Stock Data). Only mangrove biomass BCS is currently catered by the DAP, needing further development to integrate mangrove sediment and seagrass BCS. It also faces challenges on sustainability, data quality checks, and data sharing policies. Further development and implementation

of *Blue Carbon PH* is crucial to guide local BCE conservation efforts, to monitor greenhouse gas emissions and potential carbon credits, and to advance BCE research in the Philippines.

INTRODUCTION

Blue carbon ecosystems (BCEs) such as mangrove forests and seagrass beds can store 1.6-4.0 times more carbon than an equivalent area of tropical upland forest (Kauffman et al., 2020a & b). They store >50% of ocean sediment carbon despite comprising only 0.2% of the ocean surface (Macreadie et al., 2021). Thus, BCEs have huge potential to contribute to climate change adaptation and mitigation (Hilmi et al., 2021). They also function as nursery habitats for commercially important species (Whitfield, 2016) and coastal protection against flooding and erosion (Guannel et al., 2016). With these contributions, BCE conservation and restoration is of utmost importance, guided by the use of high quality, standardized blue carbon stock (BCS) data.

Data collation, quality assurance and sharing can now be made efficient using a data analytic platform (DAP). A DAP is a computer system that can analyze large, complex, and dynamic data to support data sharing and decision-making (Runkler, 2020; Worthington et al., 2020). Examples include the Global Mangrove Watch (GMW; Bunting et al., 2022) and the Coastal Carbon Atlas

*Corresponding author

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(CCA; Holmquist et al., 2023), both of which cater to global-scale data. The Indo-Pacific Blue Carbon Datahub (IPBCD; <https://bluecarbonhub.ibenthos.ai/>) is another DAP that compiles BCE data in Southeast Asia, India, and Australia. DAPs for terrestrial carbon include TEAM Network (Youn et al., 2011), IFMS (Pratihast et al., 2016), and Forest Explorer (Vega-Gorgojo et al., 2022). Through DAPs, target research gaps and policy needs are expected to be determined easily.

Despite these technologies, both global and regional BCE datasets remain limited in terms of scope and timeliness. For instance, GMW stores global BCS data up to 2016 only, while CCA and IPBCD only provide sediment BCS data from selected countries. Similar concerns were encountered in DAPs for terrestrial forests. In the Philippines, a country known for high BCE cover and biodiversity (Bunting et al., 2022; Fortes et al., 2018), a growing body of unconsolidated BCS datasets (e.g., Corcino et al., 2023) are not reflected yet in global DAPs.

A proposed solution to this is the development of a local-scale DAP, developed and maintained by the respective locality that the DAP serves. This has been done for agroforestry carbon measurements in Thailand (Samek et al., 2011; Laosuwan et al., 2011) but is inaccessible at present. In this study, we aimed to (1) develop *Blue Carbon PH*, a local-scale DAP for BCS data in the Philippines; and (2) discuss the challenges and realizations in the development, implementation, maintenance, and significance of DAPs.

MATERIAL AND METHODS

Blue Carbon PH was developed using R, one of the most utilized computer programs for bio-statistical analyses. It is an open-source programming language that has an enormous repository of codes grouped by functions for easier use and with a wide and supportive online community (Tippmann, 2014). The DAP was built in RStudio (RStudio Team, 2022) using various R packages (Supplementary Table 1). The package *shiny* (Chang et al., 2022) was the main platform-building package for both user interface (UI) and server (Figure 1). The package *rsconnect* (Atkins et al. 2024) was used for deploying the DAP online in ShinyApps.io (<https://www.shinyapps.io/>). The packages *googledrive* (D'Agostino McGowan & Bryan, 2023), and *googlesheets4* (Bryan, 2023) were used to connect the DAP to Google Cloud for data consolidation.

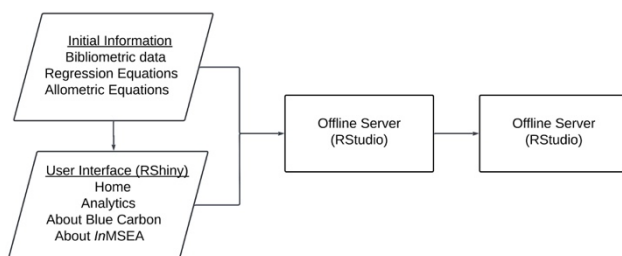


Figure 1: Flowchart of the development of Blue Carbon PH.

Equations applied in the Analytics page for computing mangrove biomass BCS include the following: (1) allometric equations for the calculations of above- and below-ground biomasses; and (2)

regression equations between BCS and environmental data (Supplementary Table 2). Biomass BCS is computed by getting 48% of the above-ground biomass and 39% of the below-ground biomass. The allometric equations are standard equations applied by various blue carbon assessment studies in the Philippines (e.g. Corcino et al., 2023; Joson et al., 2021; Salmo & Gianan, 2019; Camacho et al., 2011). One of the allometric equations was derived from Philippine field datasets (Gevaña & Im, 2016), similar to the regression equations in Corcino et al. (2023).

The DAP's biomass BCS computation component was applied during a training-workshop in Tacloban, Leyte last April 2023. Participants were from the academe, local and national government agencies, and non-government organizations. Further pilot-testing has yet to be conducted and is planned to proceed alongside the continued refinement and development of the DAP.

RESULTS AND DISCUSSION

User Interface

Blue Carbon PH (<https://inmseaproject.shinyapps.io/inmseaproject/>) consists of four pages: Home, Analytics, About Blue Carbon, and About *InMSEA*. The Home Page provides information about the overall status of BCE in the Philippines based on collated literature (see Corcino et al., 2023). The Analytics Page is where users can compute biomass BCS from raw data, as well as submit raw or computed BCS to a Google Cloud-based data storage. The About Pages give a brief overview of BCE and the developers of the web application.

Analytics

In the Analytics Page, three analytics modules were implemented (Figure 2) for computing and submitting mangrove biomass BCS data. Before selecting a module, preliminary information is requested first. These include User Information (name, affiliation, email address, and date) and geographic coordinates of the sampling area in decimal degrees.

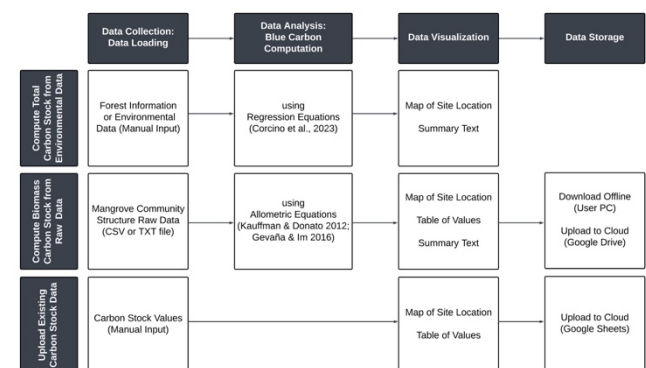


Figure 2: General flowchart of the three analytics modules of Blue Carbon PH based on the recommended science mapping workflow (top row; Aria & Cuccurullo, 2017).

In Module 1, mangrove biomass BCS can be predicted from manually inputted values of mean biomass, total mangrove area, forest age, soil porewater temperature, and mean annual precipitation.

3. Compute total carbon stocks

Choose Action

Compute Total Carbon Stock from Environmental Data

Mean (Mg/ha) 300 Biomass Total Area (ha) 20 Age of Mangrove Forest (yrs) 3 Soil Porewater Temperature (Celsius) 29 Mean Annual Precipitation (mm/yr) 1100

Compute

Results:



The computed biomass carbon stocks are:
 282.04 Mg/ha from mean total biomass,
 222.2 Mg/ha from total area,
 102.893 Mg/ha from age,
 494.962 Mg/ha from soil porewater temperature,
 1232.886 Mg/ha from mean annual precipitation.
 The national mean is at 400.4 Mg/ha (Corcino et al.)

Figure 3: Sample outputs of Module 1: “Compute Total Carbon Stock from Environmental Data” in the Analytics page of Blue Carbon PH. Users must enter at least one of the following environmental parameters: mean mangrove biomass (Mg/ha), total mangrove area (ha), age of mangrove forest (years), soil porewater temperature (°C), and mean annual precipitation (mm/yr). Upon clicking “Compute”, a map of the sampling area location and a summary of the biomass BCS estimated from the given environmental parameters are generated.

In Module 2, mangrove biomass BCS can be computed from raw mangrove vegetation data such as girth or diameter at breast height, and tree height. It can also estimate carbon “losses” from dead mangrove trees. Lastly, it offers an option to download the

computed biomass BCS of the individual trees in the raw data, as well as upload these in the Google Cloud for data sharing.

3. Compute total carbon stocks

Choose Action

Compute Biomass Carbon Stock from Raw Data

Select CSV or TXT file

Browse cstocks_ph_19Nov.csv

Upload complete

Does file have header? ☒

Separator

☒ Comma (CSV)
☐ Semicolon (CSV)
☐ Tab (TXT)

Quote

☐ None
☒ Double Quote
☐ Single Quote

Plot Type

☐ Square
☒ Circular

Plot Side or Radius (m) 7

Compute

Notes:

1. Click [here](#) to access data template.
2. Filename should be in the following format: DateSurveyed(YYYYMMDD)_Surname_Province_Municipality
3. Required columns: province, municipality, site_name, plot_id, species, gbh_cm, height_m, cw_m, ch_m, status. See data template for details.
4. Upload CSV (Comma delimited) or TXT (Tab delimited) files only.
5. If you wish to upload lat/long coordinates, name columns as 'lat' or 'long'.

status	Transect	Plot	Distance	Angle	wd	dbh_cm	plot_area_ha	basalarea_sqmha	canopycov_sqmha	agb_Mgha	bgb_Mgha	agb_
live	1	1	3	299	0.7	2.546479	0.015394	0.033084	4.591778	0.037695	0.074719	
live	1	1	5	143	0.7	14.960565	0.015394	1.141917	95.758985	1.878435	3.807407	

You may upload this to the Philippine Blue Carbon Database by clicking the “Upload to Database” button below.

Upload to Database Download table

LIVE TREES

Stem density: 3248.02 stems/ha
 Basal area: 51.86 sqm/ha
 Canopy cover: 4689.19 sqm/ha
 Dominant species: *Xylocarpus granatum*
 Aboveground biomass carbon stock: 20.88 Mg/ha
 Belowground biomass carbon stock: 85.81 Mg/ha
Total biomass carbon stock: 106.69 Mg/ha

DEAD TREES

Stem density: NaN stems/ha
 Basal area: 0 sqm/ha
 Dominant species:
 Aboveground biomass carbon stock: 0 Mg/ha
 Belowground biomass carbon stock: 0 Mg/ha
Total biomass carbon stock: 0 Mg/ha

National mean total carbon stock: 400.4 Mg/ha (Corcino et al., 2023)



Figure 4: Sample outputs of Module 2: “Compute Biomass Carbon Stock from Raw Data” in the Analytics page of Blue Carbon PH. Users must first upload a CSV or TXT file of the raw mangrove vegetation dataset and enter the shape and dimensions of the plot used. Upon clicking “Compute”, the DAP will open the dataset as a table and compute for basal area (basalarea_sqmha), canopy cover (canopycov_sqmha), biomass (agb_Mgha and bgb_Mgha), and biomass BCS (agb_C_Mgha and bgb_C_Mgha). The DAP also generates a map of the study area and summary of the biomass BCS and vegetation parameters.

In Module 3, BCS values found in published or unpublished studies can be manually encoded and directly uploaded into the Google Cloud.

Province

Palawan

Municipality/City

Puerto Princesa

Site Specifics

Bahile

Date Surveyed

2014

Aboveground Biomass Carbon Stock (Mg/ha)

1080.0945

Belowground Biomass Carbon Stock (Mg/ha)

178.2619

Sediment Carbon Stock (Mg/ha)

848.6111

Total Carbon Stock (Mg/ha)

Authors (Lastname, Firstname):

Castillo et al., 2018

Title of Study Reference

Article Type

Journal Article

Add

Reset

Please review your data inputs. To add datapoints, clear and re-fill up the form above, then click 'Add'. To remove datapoints, click the row to delete then click 'Remove Row' below.

province	lat_center	long_center	agb_C_Mgha	bgb_C_Mgha	sed_C_Mgha	total_C_Mgha
Palawan	9.8028	118.725	89.66	43.25		
Palawan	10.05083	118.7172	1080.0945	178.2619	848.6111	

Remove Row

Submit to Database

+

-

Leaflet | Tiles © Esri

Figure 5: Sample outputs of Module 3: “Upload Existing Carbon Stock Data” in the Analytics page of Blue Carbon PH. Users shall provide information on the site location (Province, Municipality/City, Site Specifics), Date of Survey, values of any of the BCS data to be uploaded, and the data source (Authors, Study Reference, Article Type). Each entry will be mapped and collated in a generated table before submission to the Google Cloud (“Submit to Database”).

Discussion

Local-scale DAPs are important in the country’s BCE monitoring. By Philippine law, BCE management is assigned to local governments. However, they usually lack the resources—expertise, finances, and manpower—to identify and monitor these ecosystems. DAPs can allow ease of access and computation of BCE data even by inexperienced local community members. They can use it to pinpoint areas with high BCS gains and losses and integrate them in coastal management plans as priority conservation and restoration sites. They can use it to objectively monitor the success rate of restoration efforts. Datasets submitted to DAPs can also be contributed to global DAPs, given the proper declaration of data sharing policies. Lastly, DAPs can serve as information and awareness material. For instance, the Home and About Pages of *Blue Carbon PH* explains the blue carbon concept in layman’s terms. This is crucial since the blue carbon concept still barely receives recognition in the local level, as in several municipalities in Eastern Samar, Aklan, Palawan, and even in Indonesia (Quevedo et al., 2021a; 2021b).

DAPs should be sustained to keep it online, running, and updated. This requires qualified personnel and funding to pay for manpower and subscriptions (e.g., for server use and cloud storage). In the Philippines, DAPs are developed through short-term (< 5 years) projects funded by government or international research grants (Corcino et al., 2023), then expectedly sustained by more ‘stable’ national and regional government agencies that have continuous financing and manpower. For the government to take this responsibility is highly dependent on its existing mandates and priority thrusts. Fortunately, BCE conservation is being integrated in the country’s blue economy agenda (DENR, 2023) and in its Intended Nationally Determined Contributions by 2025 (UNFCCC, 2024). These actions are vital for the blue carbon agenda to be more recognized and implemented in the global, national, and local scales.

CONCLUSION

Blue Carbon PH is still in its initial stages. It is yet to undergo further development and pilot testing. Major future plans include the addition of the following modules: (1) computing mangrove sediment BCS and seagrass BCS using localized equations (e.g. Salmo et al., 2024 for sediment BCS), (2) estimating carbon credits, and (3) checking for data quality and data sharing ethics. Blue Carbon PH should also cater to the general public, starting with the integration of citizen science in its modules. This encourages local community engagement in BCE conservation, and can collect enormous amounts of data with lesser costs (as in Rivera et al., 2025). Lastly, the policy integration of Blue Carbon PH can bridge science and policy. The INDC and blue carbon agenda can mandate the continued development and maintenance of the DAP. In turn, datasets collated by the DAP can support future actions and policies for BCE conservation and restoration.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

Russel Christine B. Corcino: conceptualization; web platform design and development; data gathering, processing, and analysis; manuscript writing

Severino III G. Salmo: conceptualization; project management; code review; manuscript writing

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