Carbon storage in the branchless trunk of the white mangrove *Laguncularia racemosa* (L.) in mangroves

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ABSTRACT

Objective: Estimate branchless trunk biomass and carbon storage in *Laguncularia racemosa*.

Design/methodology/approach: Dasometric inventories were conducted at 24 monitoring sites, and biomass and carbon storage were estimated using allometric equations. Wolfram Mathematica® software was utilized for simulations and to calculate the model's correlation coefficient.

Results: Maximum values of 127.08 Mg·ha^{-1} for branchless trunk biomass and 60.99 MgC·ha^{-1} for carbon storage were obtained. The simulation showed a correlation coefficient of $R^2=0.805182$ based on the collected data.

Limitations on study/implications: The study focuses exclusively on *Laguncularia racemosa* within the Ejido La Solución Somos Todos in Tabasco, Mexico, which limits the applicability of the findings to other mangrove species or regions with different environmental conditions.

Findings/conclusions: The mangroves in the Ejido La Solución Somos Todos demonstrate high biomass yield and significant carbon storage capacity. Continued research and development of conservation strategies are essential, given the critical role mangroves play in climate change mitigation.

Keywords: biomass, model, climate change

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INTRODUCTION

Mangroves cover approximately 0.7% of the surface area of the world's tropical and subtropical zones (136,000 km^2) and provide a range of ecosystem services, including carbon storage, coastal erosion prevention, biodiversity conservation, and the filtration of contaminated water through sediment retention, functioning as biological filters (Samanta *et al.*, 2021; Abino *et al.*, 2014; Peñaranda *et al.*, 2019). Despite their ecological significance, global mangrove coverage has declined by 30% over the past 50 years, resulting in the

release of substantial amounts of CO_2 into the atmosphere (Zhang *et al.*, 2022; Wang *et al.*, 2021; Hati *et al.*, 2017). Mangroves play a critical role in climate change mitigation due to their carbon sequestration capacity, storing approximately 24 teragrams (Tg) of carbon annually equivalent to roughly 3% of the total global carbon storage of tropical forests (Meng *et al.*, 2022; Wang *et al.*, 2021; Muhsoni *et al.*, 2018). In Mexico, mangrove forests span approximately 7,645 km^2, accounting for 5% of the global mangrove area (Barrios-Calderón *et al.*, 2020). In light of this, Nguyen *et al.* (2019) recommend non-destructive methods, including allometric equations and remote sensing technologies, for biomass estimation. White mangroves (*Laguncularia racemosa*) thrive in diverse environmental conditions. They are typically located on the inner fringe of mangrove ecosystems, in elevated areas with less frequent and intense tidal flooding, as well as in basin mangroves with limited tidal exchange. In these environments, white mangroves are commonly associated with black mangroves (*Avicennia germinans*), particularly where soil salinity ranges between 30 and 40 parts per thousand. In low-salinity basins, white mangrove often becomes the dominant species (Hernández-Lanuza, 2020). In Mexico, the predominant mangrove species are the red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), black mangrove (*Avicennia germinans*), and buttonwood mangrove (*Conocarpus erectus*). Other species, such as *Rhizophora harrisonii* and *Avicennia bicolor*, occur in minimal abundance. These mangroves are distributed across highly dynamic environmental gradients influenced by salinity, temperature, oxygen levels, redox potential, and varying nutrient inputs. Mexico ranks fifth globally in total mangrove area (Hernández & Junca-Gómez, 2020). Forest biomass is a key variable for assessing the role of mangroves in carbon storage and can be estimated through allometric functions that correlate biomass with tree physical attributes such as diameter at breast height, height, crown diameter, basal area, and wood density (Thuy *et al.*, 2020). White mangrove trees are also economically valuable to local communities, providing timber, posts, firewood, and charcoal (Del Trópico Húmedo, 2007). The branchless trunk is defined as the length of the tree from the base to the point of insertion of the first living branches in the crown (Romahn *et al.*, 1994). It is therefore essential to conduct research that allows for accurate estimation of carbon storage in mangroves. Such studies support informed decision-making and the development of effective strategies that integrate carbon offset mechanisms, thereby benefiting both the environment and local populations. This approach could greatly enhance mangrove conservation and restoration efforts, contributing to the long-term sustainability of these vital coastal ecosystems. Accordingly, the objective of this study is to estimate carbon storage in the branchless trunk of white mangrove (*Laguncularia racemosa*) in the ejido "La Solución Somos Todos" in Paraíso, Tabasco, Mexico.

MATERIALS AND METHODS

Study sites

The study was conducted in the ejido "La Solución Somos Todos," located in Paraíso, Tabasco, Mexico (Figure 1). The mangrove forest in this area covers approximately 1,936 hectares. The ecosystem comprises three mangrove species: red mangrove (*Rhizophora mangle*), white mangrove (*Laguncularia racemosa*), and black mangrove

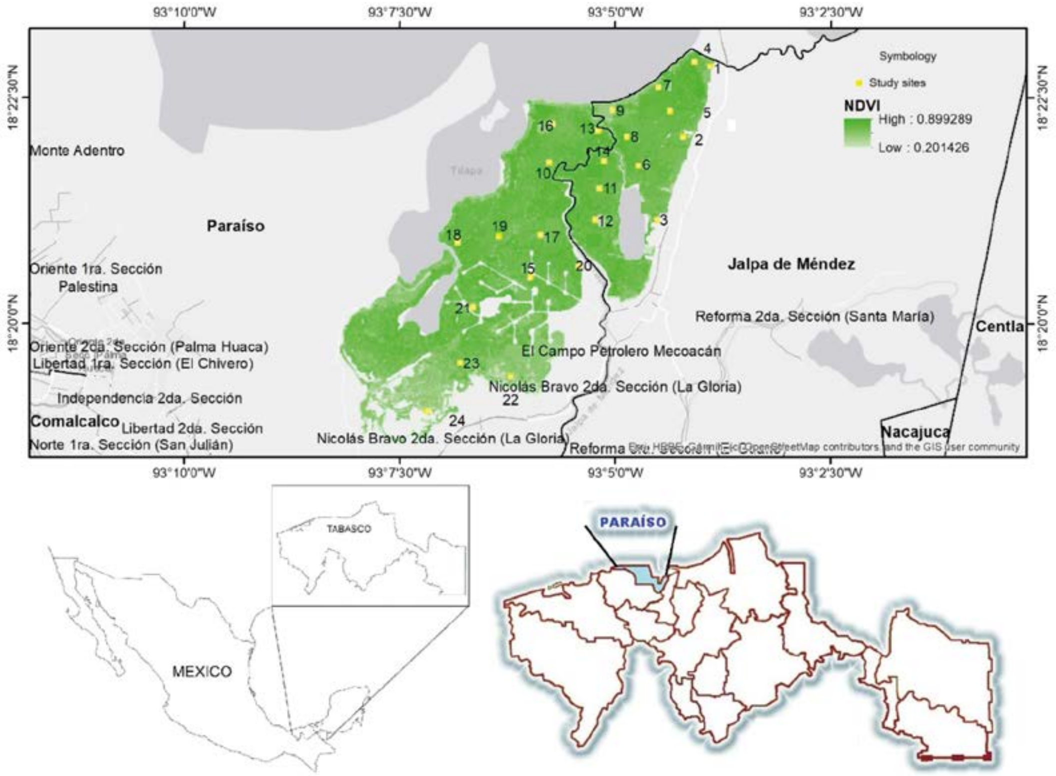


Figure 1. "Ejido la solución somos todos", Paraíso, Tabasco, México.
Source: Modified from CONABIO (2021).

(*Avicennia germinans*). This research focused on the white mangrove (*L. racemosa*) as a case study, given its ecological significance to the ejido and its dominance in terms of territorial coverage.

Data collection and inventory

The data used to estimate biomass in the branchless trunk and subsequently determine carbon storage in the mangrove ecosystem were obtained through field measurements conducted at designated plots. These activities were carried out with the support of ejido members familiar with the condition of each plot during the years 2020 and 2021. A total of 24 monitoring sites were established, with each plot measuring 30×10 meters (Marín-Cruz, 2019).

Measurements of dasometric variables

For *Laguncularia racemosa*, the variables considered included the diameter at breast height (DBH), measured at 1.30 m above ground using a diameter tape, and tree height, measured with a Haga altimeter (Kauffman *et al.*, 2013).

Estimation of biomass in the branchless trunk and stored carbon

The existing estimation of biomass in the branchless trunk was estimated through the equation carried out by Chave *et al.* (2005) and Komiyama *et al.* (2005).

$$Ba = 0.0509(\rho)(D2)(H)$$

where: Ba=biomass in the branchless trunk of trees in dry weight (Kg); ρ=wood density (g cm^{-3}); D=diameter of the tree at a height of 1.30 m and H=tree height (m). The density value for *L. racemosa* was obtained from the international database on wood density provided by the website (http://db.worldagroforestry.org//wd). Fc=conversion of 0.48.

The biomass in the branchless trunk obtained from L. racemosa was multiplied by the conversion factor of 0.48 used for *L. racemosa* by Velázquez-Pérez *et al.* (2019) and Kauffman *et al.* (2013). The average values of biomass in the branchless trunk (Mg·ha^{-1}) were calculated and multiplied by this factor.

Estimation of the uncertainty of the selected model through simulation

Wolfram Mathematica® software was used to perform mathematical simulations. Once the simulations for the n cases were completed, the results were exported for further analysis.

Equation models for estimating biomass and its correlation coefficient R^2

Model fitting was performed using the statistical criterion of the correlation coefficient (R^2). In this study, a correlation test was applied to assess the degree of association between the dasometric variables (tree diameter and height) and the estimated biomass of the branchless trunk in *Laguncularia racemosa* mangroves.

RESULTS AND DISCUSSION

Diameter-height distribution

In the ejido, *Laguncularia racemosa* exhibited a diameter at breast height (DBH) range from 1.11 to 33.26 cm and a height range from 3 to 25 meters (Figure 2). In mature mangrove forests, trees typically display larger DBH values due to prolonged growth, meaning that older trees with greater DBH contribute more substantially to carbon storage. In contrast,

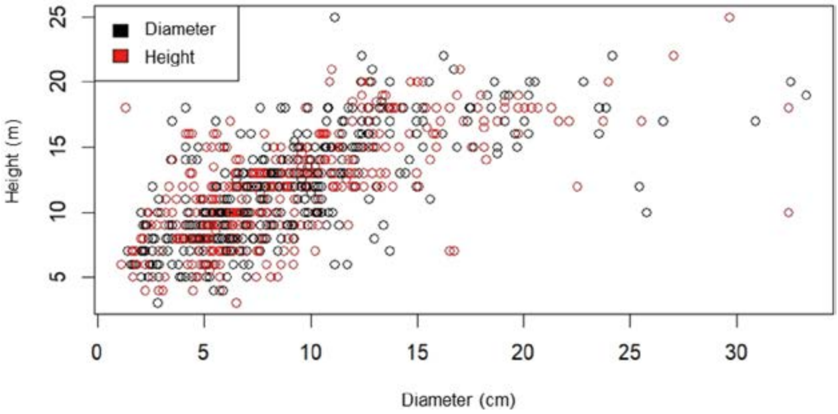


Figure 2. Height and diameter distribution of *L. racemosa* trees.
Source: Own elaboration.

regenerating mangroves are characterized by smaller DBH values, indicating younger or early-stage trees. While these trees also contribute to carbon storage, their contribution is significantly lower compared to that of mature trees.

Biomass in the branchless trunk (AB) and estimation of stored carbon

The study reports maximum biomass values of up to 127.08 Mg·ha^{-1} and carbon storage of 60.99 MgC·ha^{-1} in sites with mature trees. A higher DBH in these trees reflects a greater carbon sequestration capacity, as a larger volume of woody material is accumulated in the trunk. In sites with regenerating mangroves, DBH values are smaller, and carbon storage can be as low as 3.92 MgC·ha^{-1} (Table 1).

In this study, the average biomass in the branchless trunk across all sampling sites was 63.97 Mg·ha^{-1}, with an average carbon storage of 27.79 MgC·ha^{-1} for the single

Table 1. Average biomass in the branchless trunk and stored carbon of white mangrove at the study sites.

Site	Average biomass in the branchless trunk (Mg ha^{-1})	Stored carbon (MgC ha^{-1})
1	98.67	47.36
2	8.79	4.21
3	127.08	60.99
4	71.06	34.10
5	11.63	5.58
6	97.84	46.96
7	117.56	56.42
8	97.64	46.86
9	73.39	35.22
10	79.83	38.31
11	88.83	42.63
12	20.62	9.89
13	43.98	21.11
14	15.32	7.35
15	98.62	47.33
16	98.54	47.29
17	17.96	8.62
18	8.18	3.92
19	60.88	29.22
20	89.15	42.79
21	105.54	50.65
22	40.73	19.55
23	37.59	18.04
24	26.00	12.48
	$\bar{x}=63.97$	$\bar{x}=30.70$

Mg ha^{-1}=Megagrams per hectare. MgC ha^{-1}=Megagrams of carbon per hectare. Source: Own elaboration.

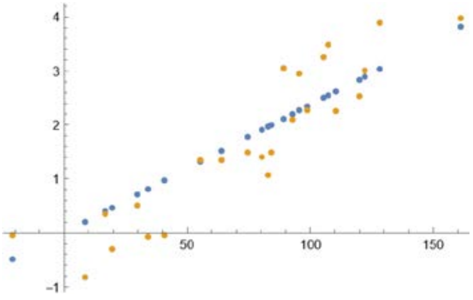
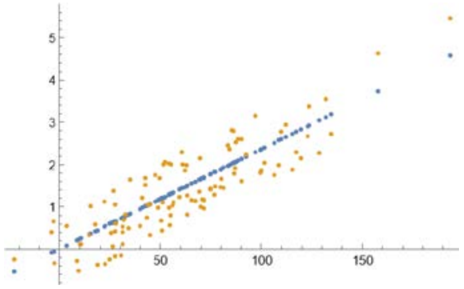
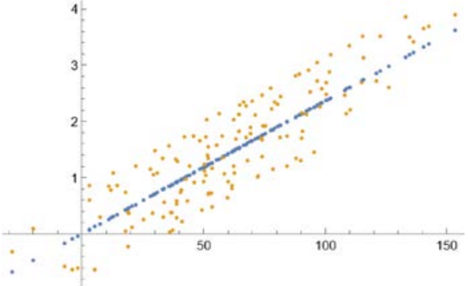
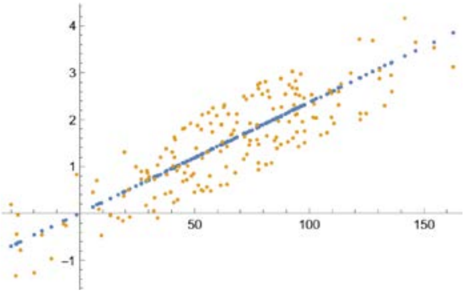
case study species, *Laguncularia racemosa*. The results are globally comparable to those reported by Blanco-Libreros *et al.* (2015) in the Darién Region of Colombia, where *L. racemosa* exhibited branchless trunk biomass values of 12.4, 6.2, 5.5, and 6.4 Mg·ha^{-1} across four study sites, and corresponding carbon storage values of 6.2, 3.1, 2.7, and 3.2 MgC·ha^{-1}, respectively. This research recorded a maximum branchless trunk biomass of 127.08 Mg·ha^{-1} and carbon storage of 60.99 MgC·ha^{-1}. Nationally, these results align with findings by Bautista-Olivas *et al.* (2018) in Bahía del Sargento, Sonora, Mexico, where *L. racemosa* showed a branchless trunk biomass of 81.5 Mg·ha^{-1} and an estimated carbon storage of 40.7 MgC·ha^{-1}. Similarly, in Bahía del Sargento, Mendoza-Cariño *et al.* (2022) reported branchless trunk biomass of 104.1 Mg·ha^{-1} and carbon storage of 52.1 MgC·ha^{-1} for *L. racemosa*. In La Paz Bay, Baja California Sur, Ochoa-Gómez *et al.* (2019) documented an average branchless trunk biomass of 93.8 Mg·ha^{-1} and carbon storage of 43.5 MgC·ha^{-1}. At the regional and local levels, in the mangroves of Ciudad del Carmen, Campeche, Hernández-Nava *et al.* (2022) estimated biomass in the branchless trunk at 109 Mg·ha^{-1} and stored carbon at 50.5 MgC·ha^{-1} for *L. racemosa*. In the Úrsulo Galván mangroves of Tabasco, Ávila-Acosta *et al.* (2024) reported branchless trunk biomass of 99.5 Mg·ha^{-1} for the same species.

Estimation of the uncertainty of the selected model through simulation and correlation coefficient

Table 2 presents the results of biomass simulations based on increasing sample sizes of the D^2H composite variable. When the number of samples matches the actual field observations (n=24), the fitted curve is $B=0.0241137D^2H$, closely aligning with the selected allometric model: $B=0.0236176D^2H$. The resulting correlation coefficient ($R^2=0.805182$) indicates a strong fit between the simulated values and observed biomass, with minimal standard deviation. When the sample size increases to 105, the fitted curve becomes $B=0.0229619D^2H$, also closely resembling the selected model, and the correlation coefficient remains high ($R^2=0.74067$), confirming a good model fit. The simulation approach enabled the calibration and validation of complex mathematical models linking dasometric variables (*e.g.*, tree diameter and height) to biomass. By applying allometric equations, Wolfram Mathematica® accurately estimated branchless trunk biomass. The high correlation coefficient ($R^2=0.805182$) demonstrates strong agreement between simulated and observed data, reflecting the method's precision. Simulations were performed for multiple sample sizes (24, 105, 140, 175), allowing observation of how correlation coefficients varied with sample size. This use of simulation contributes to a better understanding of data variability and helps refine allometric models for more robust biomass estimates.

Models developed for *Laguncularia racemosa* have demonstrated that even with relatively small sample sizes, a high degree of accuracy can be achieved. For instance, Correa (2002) reported a correlation coefficient of $R^2=0.982$ with a sample size of n=19. Similarly, Fromard *et al.* (1998) achieved an $R^2=0.97$ using a sample of n=70. These findings indicate that allometric models can yield highly accurate estimations of biomass even with limited data, reinforcing their reliability for ecological and carbon storage studies.

Table 2. Biomass simulation and fitted curves based on varying sample sizes.

Sample	Fitted model simulated	R^2	Graphic representation
24	$0.0241137D^2H$	0.805182	
105	$0.0229619D^2H$	0.740670	
140	$0.0246378D^2H$	0.758135	
175	$0.0229374D^2H$	0.721673	

D^2H=Composite variable (D=diameter, H=height). *Blue dots: curve fitting with simulated data; orange dots: simulated biomass with standard deviation; X axis: Composite Variable; Y axis: Total biomass. Source: Own elaboration.

CONCLUSIONS

Mangroves play a crucial role in climate change mitigation due to their capacity to store carbon. The results of this study revealed considerable variation in branchless trunk biomass and carbon storage in Laguncularia racemosa across the study sites, with maximum values reaching 127.08 $Mg·ha^{-1}$ and 60.99 $MgC·ha^{-1}$, respectively. The simulation yielded a correlation coefficient of $R^2=0.805182$, indicating a strong fit between the simulated data and the estimated biomass with standard deviation.

This study emphasizes the vital role of mangroves particularly *L. racemose* in carbon sequestration and their contribution to mitigating climate change. The findings demonstrate that the mangroves in the ejido "La Solución Somos Todos" in Paraíso, Tabasco, Mexico, possess substantial branchless trunk biomass and store significant amounts of carbon. These results underscore the need for ongoing research and the development of conservation strategies aimed at protecting and restoring mangrove ecosystems, both regionally and globally, given their critical role in maintaining environmental balance and combating climate change.

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REFERENCES

Abino, A. C., Castillo, J. A. A., & Lee, Y. J. (2014). Species diversity, biomass, and carbon stock assessments of a natural mangrove forest in Palawan, Philippines. *Pak. J. Bot, 46*(6), 1955-1962.

Ávila-Acosta, C. R., Domínguez-Domínguez, M., Vázquez-Navarrete, C. J., Acosta-Pech, R. G., & Martínez-Zurimendi, P. (2024). Aboveground Biomass and Carbon Storage in Mangrove Forests in Southeastern Mexico. *Resources, 13*(3), 41. https://doi.org/10.3390/resources13030041

Barrios-Calderón, R. D. J., Mata, D. I., Flores-Garnica, J. G., Jong, B. H. J. D., Monzón Alvarado, C., & Maza-Villalobos Méndez, S. (2020). Análisis comparativo de camas de combustibles forestales en un ecosistema de manglar. *Madera y bosques, 26*(1). https://doi.org/10.21829/myb.2020.2611950

Bautista-Olivas, A. I., Mendoza-Cariño, M., Cesar-Rodriguez, J., Colado-Amador, C. E., Robles-Zazueta, C. A., & Meling-López, A. E. (2018). Biomasa aérea y captura de carbono en manglares de la zona árida del noroeste de México: Bahía del Tóbari y estero El Sargento, Sonora. *Revista Chapingo Serie Ciencias Forestales y del Ambiente, 24*(3), 387-403. https://doi.org/10.5154/r.rchscfa.2018.02.020

Blanco-Libreros, J. F., Ortiz-Acevedo, L. F., & Urrego, L. E. (2015). Reservorios de biomasa aérea y de carbono en los manglares del golfo de Urabá (Caribe colombiano). *Actualidades Biológicas, 37*(103), 131-141. https://doi.org/10.17533/udea.acbi.v37n103a02

Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., & Yamakura, T. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145, 87-99. http://dx.doi.org/10.1007/s00442-005-0100-x

Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO) (2021).

Correa, M.A. 2002. Ecuaciones de biomasa y existencias de carbono de *A. germinans* y *L. racemosa* en el delta del Río Ranchería. Manuscrito Proyecto ColcienciasUniversidad de La Guajira, Medellín, Colombia. 11 p.

Del Trópico Húmedo, C. D. A. (2007). Diagnóstico del Estado Actual de los Manglares, su Manejo y su Relación con la Pesquería en Panama. Recomendaciones para el manejo sostenible del bosque de manglar en el Golfo de Chiriquí.

Fromard, F., H. Puig, E. Mougin, G. Marty, J.L. Betoulle & L. Cadamuro. 1998. Structure, above-ground biomass and dynamics of mangrove ecosystems: new data from French Guiana. *Oecologia* 115: 39-53.

Hati, J. P., Samanta, S., Chaube, N. R., Misra, A., Giri, S., Pramanick, N., & Hazra, S. (2021). Mangrove classification using airborne hyperspectral AVIRIS-NG and comparing with other spaceborne hyperspectral and multispectral data. *The Egyptian Journal of Remote Sensing and Space Science, 24*(2), 273-281. https://doi.org/10.1016/j.ejrs.2020.10.002

Hernández-Nava, J., Pascual-Barrera, A. E., Zaldívar-Jiménez, A., & Pérez-Ceballos, R. (2022). Estructura y secuestro de carbono en manglares urbanos, fundamentos para su conservación en Isla del Carmen, Campeche, México. *Botanical Sciences, 100*(4), 899-911. https://doi.org/10.17129/botsci.3048

Hernández-Lanuza, C. Y. (2020). Evaluación de la estructura forestal del ecosistema Manglar en el Manchón Guamuchal (Doctoral dissertation, USAC).

Hernández, M. E., & Junca-Gómez, D. (2020). Carbon stocks and greenhouse gas emissions (CH_4 and N_2O) in mangroves with different vegetation assemblies in the central coastal plain of Veracruz Mexico. *Science of The Total Environment*, 741, 140276. https://doi.org/10.1016/j.scitotenv.2020.140276

Kauffman, J. B., Donato, D. C., & Adame, M. F. (2013). Protocolo para la medición, monitoreo y reporte de la estructura, biomasa y reservas de carbono de los manglares (Vol. 117). Cifor.

Komiyama, A., Poungparn, S., & Kato, S. (2005). Common allometric equations for estimating the tree weight of mangroves. *Journal of tropical ecology, 21*(4), 471-477.

Marín-Cruz, G. (2019). Servicio ecosistémico de carbono almacenado en manglares: UMA la solución somos todos en Tabasco (Master's thesis).

Meng, Y., Gou, R., Bai, J., Moreno-Mateos, D., Davis, C. C., Wan, L., & Lin, G. (2022). Spatial patterns and driving factors of carbon stocks in mangrove forests on Hainan Island, China. *Global Ecology and Biogeography, 31*(9), 1692-1706. https://doi.org/10.1111/geb.13549

Mendoza-Cariño, M., Bautista-Olivas, A. L., Duarte-Tagles, H. F., & Celaya-Michel, H. (2022). Economic value of aboveground mangrove biomass carbon storage in Sonora, Mexico Valor económico del almacén de carbono en biomasa aérea de manglares de Sonora, México. *Revista Chapingo Serie Ciencias Forestales y del Ambiente, 28*(3). https://doi.org/10.5154/r.rchscfa.2021.09.056

Muhsoni, F. F., Sambah, A. B., Mahmudi, M., & Wiadnya, D. G. R. (2018). Comparison of different vegetation indices for assessing mangrove density using sentinel-2 imagery. *GEOMATE Journal, 14*(45), 42-51. https://doi.org/10.21660/2018.45.7177

Nguyen, L. D., Nguyen, C. T., Le, H. S., & Tran, B. Q. (2019). Mangrove mapping and above-ground biomass change detection using satellite images in coastal areas of Thai Binh Province, Vietnam. http://dx.doi.org/10.24259/fs.v3i2.7326

Ochoa-Gómez, J. G., Lluch-Cota, S. E., Rivera-Monroy, V. H., Lluch-Cota, D. B., Troyo-Diéguez, E., Oechel, W., & Serviere-Zaragoza, E. (2019). Mangrove wetland productivity and carbon stocks in an arid zone of the Gulf of California (La Paz Bay, Mexico). *Forest ecology and management*, 442, 135-147. https://doi.org/10.1016/j.foreco.2019.03.059

Peñaranda, M. L. P., Kintz, J. R. C., & Salamanca, E. J. P. (2019). Carbon stocks in mangrove forests of the Colombian Pacific. Estuarine, *Coastal and Shelf Science*, 227, 106299. https://doi.org/10.1016/j.ecss.2019.106299

Romahn de la Vega, C. F., Ramírez Maldonado, H., & Treviño García, J. L. (1994). Dendrometría. Universidad Autónoma Chapingo.

Santa, V., Rosa, M. J., Mónaco, N., & Heguiabehere, A. (2013). Determinación de la correlación entre datos de biomasa obtenidos a campo y ndvi obtenidos por sensores remotos a lo largo del arroyo Chucul (Pcia. Córdoba).

Samanta, S., Hazra, S., Mondal, P. P., Chanda, A., Giri, S., French, J. R., & Nicholls, R. J. (2021). Assessment and attribution of mangrove Forest changes in the Indian Sundarbans from 2000 to 2020. *Remote Sensing, 13*(24), 4957. https://doi.org/10.3390/rs13244957

Thales da Motta-Portillo, J., Londe, V., & Araújo-Moreira, F. W. (2017). Erratum to: Aboveground biomass and carbon stock are related with soil humidity in a mangrove at the Piraquê-Açu River, southeastern Brazil. *Journal of Coastal Conservation*, 21, 571-571. https://doi.org/10.1007/s11852-016-0482-4

Thuy, H. L. T., Tan, M. T., Van, T. T. T., Bien, L. B., Ha, N. M., & Nhung, N. T. (2020). Using sentinel image data and plot survey for the assessment of biomass and carbon stock in coastal forests of Thai Binh province, Vietnam. *Applied Ecology & Environmental Research, 18*(6). http://dx.doi.org/10.15666/aeer/1806_74997514

Velázquez-Pérez, C., Tovilla-Hernández, C., Romero-Berny, E. I., & Jesús-Navarrete, A. D. (2019). Estructura del manglar y su influencia en el almacén de carbono en la Reserva La Encrucijada, Chiapas, México. *Madera y bosques, 25*(3). https://doi.org/10.21829/myb.2019.2531885

Wahlang, R., & Chaturvedi, S. S. (2020). Relationship Between Above-Ground Biomass and Different Vegetation Indices of Forests of Ri-Bhoi District, Meghalaya, India. *Int. J. Eng. Tech. Res*, 9.

Wang, G., Singh, M., Wang, J., Xiao, L., & Guan, D. (2021). Effects of marine pollution, climate, and tidal range on biomass and sediment organic carbon in Chinese mangrove forests. *Catena*, 202, 105270. https://doi.org/10.1016/j.catena.2021.105270

Zhang, R., Jia, M., Wang, Z., Zhou, Y., Mao, D., Ren, C., & Liu, X. (2022). Tracking annual dynamics of mangrove forests in mangrove National Nature Reserves of China based on time series Sentinel-2 imagery during 2016-2020. *International Journal of Applied Earth Observation and Geoinformation*, 112, 102918. https://doi.org/10.1016/j.jag.2022.102918