Comparison of mangrove carbon sequestration in Gambia with global equivalents

This note compares the potential for carbon sequestration through mangrove sequestration with data from other global mangrove formations. The basic information source is the global biomass estimates produced by the European Space Agency (ESA) through their Climate Change Initiative (CCI) [https://climate.esa.int/en/projects/biomass/]. This provides of terrestrial woody biomass at 100 m pixel resolution in a dataset that can be freely downloaded for analysis. We have intersected the most current version of this data (2021) with the global map of WWF ecoregions originally developed by Olsen et al (2001)[1], and updated by Dinerstein et al (2017)[2]. An interactive map of global ecoregions, with links to detailed descriptions, is available at https://ecoregions.appspot.com/.

Table 1 : Carbon sequestration by global mangrove ecoregions

		Above Ground Biomass (dry matter) tons/ha				Potential CO_2 sequestered, tonnes		
Ecoregion	Ecoregion area km^2	Mean, all pixels	Highest pixel value	Upper 95% CL of mean	99% quantile pixel value	Mature CO_2/ha	Rate CO_2/ha/yr	30-year accrual
Central African mangroves	30,787	81.04	624	409.97	490	844.4	16.9	506.7
East African mangroves	2,195	16.43	128	85.13	90	155.1	3.1	93.1
Guinean mangroves	23,421	35.23	405	180.47	270	465.3	9.3	279.2
Madagascar mangroves	5,187	11.84	103	57.37	90	155.1	3.1	93.1
Red Sea mangroves	1,159	0.05	126	4.2	10	17.2	0.3	10.3
Southern Africa mangroves	992	18.16	88	87.81	90	155.1	3.1	93.1
New Guinea mangroves	26,699	116.58	544	428.42	390	672.1	13.4	403.3
Godavari-Krishna mangroves	6,980	1.03	84	14.59	50	86.2	1.7	51.7
Indochina mangroves	26,762	18.19	347	131.13	190	327.4	6.5	196.5
Indus River Delta-Arabian Sea mangroves	5,990	0.91	103	13.8	50	86.2	1.7	51.7
Myanmar Coast mangroves	21,238	26.35	386	184.52	270	465.3	9.3	279.2
Sunda Shelf mangroves	37,280	51.72	388	249.99	290	499.8	10.0	299.9
Sundarbans mangroves	20,383	11.18	116	69.26	110	189.6	3.8	113.7
Amazon-Orinoco-Southern Caribbean mangroves	40,894	69.42	330	298.81	270	465.3	9.3	279.2
Bahamian-Antillean mangroves	21,907	16.56	506	108.29	150	258.5	5.2	155.1
Mesoamerican Gulf-Caribbean mangroves	26,658	23.77	261	123.63	170	293.0	5.9	175.8
Northern Mesoamerican Pacific mangroves	8,174	3.46	173	35.24	70	120.6	2.4	72.4
South American Pacific mangroves	13,461	90.2	383	383	350	603.2	12.1	361.9
Southern Atlantic Brazilian mangroves	10,025	60.25	500	288.12	290	499.8	10.0	299.9
Southern Mesoamerican Pacific mangroves	7,827	26.53	229	151.25	190	327.4	6.5	196.5

There are 20 identified mangrove ecoregions listed in Table 1. Gambian mangroves come within the Guinean mangrove ecoregion (see https://www.oneearth.org/ecoregions/guinean-mangroves/ for a description of plant and animal species). In terms of biomass, the analysis of satellite data shows an area of 23,421 km2 for the whole ecoregion (of which about 853 km^2 is extent Gambian mangrove[3]). Three measures of asymptotic, or maximum attainable biomass are shown:

- The highest pixel has 405 tons/ha above ground woody dry matter.
- The upper 95% confidence limit of the biomass distribution is 180 tons/ha dry matter.
- The 99% quantile of the biomass distribution is 270 tons/ha dry matter.

[1] Olson, DM; Dinerstein, E; Wikramanayake, ED; et al (2001) Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51(11):933-938. https://doi.org/10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2.

[2] Dinerstein, E; David Olson, D; Joshi, A; et al (2017) An ecoregion-based approach to protecting half the terrestrial realm. BioScience 67: 534–545, https://academic.oup.com/bioscience/article/67/6/534/3102935.

[3] Bayo, B., Habib, W., & Mahmood, S. (2022) . Spatio-temporal assessment of mangrove cover in the Gambia using combined mangrove recognition index. Advanced Remote Sensing, 2 (2), 74-84.

The 99% quantile is probably the best indicator of peak attainable biomass. The single-pixel maximum is too subject to anomalies in the algorithms used. The 95% confidence limit depends on assumptions about the shape of the probability distribution. The 99% quantile is a non-parametric measure that is robust and comparable between ecoregions. This measure is therefore expanded in terms of CO_2 sequestered in the last three columns of Table 1.

Climax or mature Guinean mangrove formations can be expected to sequester 465 tons/ha CO_2. It is assumed this will take 50 years, giving and average sequestration rate of 9.3 tons/ha/yr of CO_2. After 30 years, a project for mangrove restoration could be expected to have sequestered 279 tons/ha.

These are purely above-ground woody carbon. IPCC 2013 guidelines[4] suggest a root:shoot ratio of 49%. More recent research suggest this is too low, with figures above 100% being likely[5,6], in some cases as high as 200-400%. However, the higher figures are likely associated with accruals of buried carbon over time in old-growth mangroves, and for restoration projects, the IPCC guideline figure of 49% is probably conservative and realistic.

Our estimated above ground sequestration rate from Table 1 of 9.3 tons CO_2/ha/yr can be compared with Alongi's (2012)[6] stated above-ground net primary production (NPP) of 11.2 tons/ha/yr. That is in terms of dry weight, so CO_2 equivalent is 19.30 t/ha/yr. Not all NPP ends up as woody biomass, with ratios depending on measurement criteria, leaf turnover, etc, and typical ratios being 40-70%[7], so our estimate is comparable to that of Alongi.

Considering therefore the above points we have therefore the summary shown in Table 2.

Table 2 : Above and below ground carbon sequestration rates for Guinean Mangrove Ecoregion
(including Gambia, all figures tonnes/ha CO_2 sequestered)

	Sequestration Rate, First 30 years	Total sequestered after 30 years	Long-term total sequestered (50 yr+)
Above ground	9.3	279.2	465.3
Below ground (roots)	4.6	136.8	228.0
Total	13.9	416.0	693.3

These robust estimates do depend on the application optimum species selection, planting and tending techniques. These are only likely to be achieved with good prior experience and research in the region. Where this is not available, a 5-10 year start-up period should be assumed with significant investment in nursery technique, species selection, trial plantings, and close monitoring of trial results.

Denis Alder, D.Phil.
Consultant in Forest Biometrics

[4] Table 4.5, page 4.14, https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_separate_files/WS_Chp4_Coastal_Wetlands.pdf

[5] Gillerot, LE; Vlaminck, DJR; De Ryck, DM et al. (2018) Inter- and intraspecific variation in mangrove carbon fraction and wood specific gravity in Gazi Bay, Kenya. Ecosphere 9(6):e02306. 10.1002/ecs2.2306

[6] Alongi, Daniel M (2012) Carbon sequestration in mangrove forests, Carbon Management, 3:3, 313-322, DOI: 10. 4155/cmt.12.20.

[7] Section 10.6.2.1, https://www.sciencedirect.com/topics/earth-and-planetary-sciences/net-primary-production.