Riparian Trees' Resilience amid Climate Crisis - Carbon Sequestration Potential of Riparian Trees in the Tourism Sites cradled in the protected areas of Cauvery River Basin of Southern India

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Abstract -While human lives are ephemeral, Cauvery is eternal. As the planet grapples with climate emergency due to anthropogenic actions, Riparian Trees of Cauvery River Basin (CRB) stand as vital guardians with their significant protentional for sequestering carbon. This study highlights Carbon Sequestration Potential of Riparian Trees in the tourism sites of Talakaveri and Muthathi nestled in the protected areas of the CRB using ground based non-destructive method. Talakaveri, situated in Talakaveri Wildlife Sanctuary, neighbouring the Brahmagiri Wildlife Sanctuary witness diverse range of riparian tree species demonstrating significant carbon sequestration potential, whereas Muthathi despite harbouring fewer riparian tree species exhibit higher carbon sequestration potential primarily attributed tothe presence of Terminalia arjuna (Roxb.) Wight & Arn., a keystone species in the CRB. The study unveils the pivotal role riparian trees play in carbon sequestration within the CRB, thus becoming a beacon of hope for mitigating climate crisis and safeguarding the legacy of the river Cauvery.

Keywords: Riparian Tree, Carbon Sequestration Potential, Keystone Species, Climate Change, Total Biomass, CO_2 equivalent

INTRODUCTION

The Riparian Trees of the Cauvery River Basin (CRB) are the Storytellers of Cauvery's antient tale, from the time when *Agasthya* sprang Cauvery to life (Eck, 2012) to now where the fate of its course is decided in the Courts, these faithful companions have witnessed Cauvery selflessly serving humanity.

Human civilization has flourished on the banks of the rivers and the riparian trees hold timeless narratives of its progress. As 'climate change' has evolved into 'climate crisis' the earth is scouring through for solutions to combat the emergency. Riparian forests do not exist in isolation; they are a living metaphor for the interconnectedness of the natural world. Being "interactive zone of green and blue infrastructure," (Nakamura, 2022) they are uniquely susceptible to the climate change. Their distinctive topographic location places them at the intersection of terrestrial and aquatic ecosystems, them susceptible to impacts both within the riparian zone and from the surrounding landscape, influenced by both direct climate stimuli and indirect effects . (Capon *et al,.*2013).

Riparian trees are equipped with essential traits for surviving climate change challenges like flooding, drought, and changing nutrient levels. They feature flexible growth forms and multi-stemmed structures for stability and resource acquisition during floods. Their extensive, deep root systems with specialized tissues support gas exchange in waterlogged soils, while adaptable crowns and varied leaf shapes optimize light capture and water use. Physiologically, they adjust water use efficiency, tolerate flooding through anaerobic respiration, and exploit nutrient-rich sediments. Their reproductive strategies align with flood cycles, enabling seeds to remain dormant until conditions improve. These traits reflect the intricate adaptability that sustains the riparian ecosystem, preserving its essence in the face of an ever-changing world. (Fischer et al., 2021; Baniya et al., 2019; García & Jáuregui, 2020; Rubio-Ríos et al., 2022)

Riparian trees offer plethora of ecosystem services (Deepthi *et al.,* 2019,Riis *et al.,* 2020) and therefore have sustained communities for generations. Today, as ourplanet grapples with climate crisis, the riparian trees wield significant potential to accumulate carbon stocks (Dybala *et al.,* 2019) thus contributing to the essential process of sequestering carbon.

Carbon Sequestration is "the process of storing carbon in a carbon pool" (IPCC, 2021). The concept of carbon sequestration potential embodies the inherent capacity within natural systems be they forests, soils or technological solutions to draw in and sequester carbon dioxide (CO_2) from the atmosphere. This process serves a pivotal role in our quest to temper the relentless advance of climate change by reducing the presence of CO_2 in the atmosphere.Riparian Trees act as important carbon pools, their unique ecological conditions enhance their effectiveness as carbon sinks,the riparian ecosystems possess the capacity to store a greater amount of carbon per unit area than the adjacent floodplains. (Sutfin *et al.,* 2016)

This paper focuses on examining the profound Carbon Sequestration Potential of realm of Riparian Trees in the Tourism sites of two protected areas of the Cauvery River Basin (CRB) of Southern India emphasizing the importance of preserving these silent sentinels not only for their ecological benefits but also for their potential to contribute to global carbon management efforts.

1 Study Area

1.1Cauvery River

The pristine Peninsular River Cauvery known as *'Dakshina Ganga'* is the eighth largest Indian river, with its basin covering approximately 2.7% of the country's total geographic area. The celestial crystalline waters of River Cauvery sprouts from the *Brahmagiri* Hills in the Western Ghats, the river then continues its journey towards the southeastern direction for 805 km covering two major Indian states namely Karnatakaand Tamil Nadu (320 Km in Karnataka, 416 Km in Tamil Nadu and 64 Km common border between the two states); nourishing millions it finally enters Bay of Bengal through *Poompuhar* (GOI,2017).The CRB approximately covers the area of 81,155 km^2 incorporating three States and a Union Territory namely TamilNadu (43,856Km^2);Karnataka (34,273Km^2);Kerala(2,866Km^2) and Puducherry (160 Km^2). (Chidambaram *et al.,* 2018)

1.2 Cauvery River Basin (CRB)

The CRB is majorly impacted by the South-West monsoon in the States of Karnataka& Kerala and North-East monsoon in the State of Tamil Nadu. In Karnataka, the average rainfall within the CRB ranges from 600 mm to 800 mm.(CWC, 2014). The CRB's catchment area comprises three sub-basins: Upper Cauvery, Middle Cauvery, and Lower Cauvery. The Upper Cauvery sub-basin is entirely located within Karnataka. The Middle Cauvery sub-basin is primarily situated in Tamil Nadu with a part in Karnataka. Meanwhile, the Lower Cauvery sub-basin is confined to the plains of Tamil Nadu. Offering a harmonious blend of cultural heritage and natural beauty, CRB hosts plethora of tourism and religious sites, this study focuses on two of the religious sites nestled in the protected areas of the upper and middle cauvery basin which are renowned for attracting tourists -*Talakaveri* and *Muthathi*. (EMPRI,2017)

1.1*Talakaveri* (Talakaveri Wildlife Sanctuary)

Nestled in the *Brahmagiri* Hills of the Western Ghats, *Talakaveri* (translation-base of river Cauvery) marks the origin of River Cauvery. The *Talakaveri* Wildlife Sanctuary (TWS) established in the year 1987 derives its name from this sacred shrine, it is located in the western border of *Kodagu* district of Karntaka. Owing to varying elevation (100 metersto over 1500 meters above mean sea level,it encompasses a diverse array of vegetation types, starting with semi-evergreen and low-elevation wet evergreen forests along the western boundary. As the elevation increases, these landscapes gradually transition into medium-elevation wet evergreen forests, eventually giving way to montane shola-grasslands at the highest altitudes. (Jathanna,2014, Gupta *et al.,* 2016)The annual *Tula Sankramana* festival is celebrated with great fervor, on this day Cauvery emerges from the spring in a small pond of *Talakaveri* at the exact moment when the sun enters *tula rasi* (Libra constellation), (Jayaprakash, 2018) it marks the southward movement of Sun (Siddaiah, 2016)

1.2 *Muthathi*(Cauvery Wildlife Sanctuary)

Muthati,a village in the Cauvery Wildlife Sanctuary (CWS)in *Mandya* District is a place of revered religious importance, one of the major shrines of CWS - *Muthatheraya* Temple dedicated to Lord Hanuman is situated here (Daniel *et al.,* 2012). CWS derives its name from the sacred river Cauvery whichtraverses 105 kilometers through this protected area, it is an interconnected landscape where the majestic Eastern and Western Ghats converge. With altitudes ranging from 254 meters to 1514 meters above mean sea level, the CWS is characterized by a diverse array of vegetation, including dry deciduous, woodland savanna, and riparian species, alongside moist deciduous, thorny scrub, bamboo forest, and semi-evergreen varieties (Gubbi *et al.,* 2021).

METHODOLOGY

Ground based, non-destructive method using allometric equations was used for biomass estimation. Three 25m X 25m plots were laid at 100m distance on either side of the river at the study area using simple random sampling (Diekmann, 2007).

The riparian trees within the observation plots were identified down to the species level, counted, and their diameter at breast height (DBH) (measured at 1.3 meters) was recorded to estimate the Above-Ground Biomass (AGB) and Below-Ground Biomass (BGB).

The following allometric equations wereemployed to determine AGB and BGB (Jain *et al.*, 2023;MacDicken 1997; Brown *et al.*,1989)

$$AGB = 34.4703 - 8.0671D + 0.6589D^2$$

wherein D is the DBH (cm)

$$BGB = AGB \times 0.26$$

Total Biomass (TB) :- the Total Biomass (TB) of a treeis the sum of the Above Ground Biomass (AGB) and Below Ground Biomass(BGB)

$$TB = AGB + BGB$$

Carbon Content: -Typically, for any plant species, it is estimated that 50% of its biomass constitutes carbon content. (Ravindranath *et al.*, 1997)

$$Carbon\ Content = \frac{Total\ Biomass\ (TB)}{2}$$

CO_2 equivalent is then calculated employing the following equation:

$$CO_2 = \frac{Carbon\ Content\ X\ 44}{12}$$

RESULTS AND DISCUSSION

The study documented a total of forty-two tree species in the area. In *Talakaveri*,a total number of 179 individual trees representing twenty-three different species were identified, while in *Muthathi*, a total of 67 individual trees representing eleven different species were recorded.

Table 1Comparison of Tree Diversity and Carbon Sequestration in Talakaveri (in TWS) and Muthathi(in CWS)

Particulars	*Talakaveri*		*Muthathi*	
No. of individual trees	179		67	
No. of Species	23		11	
Total Biomass (Kg)	132037.37		543883	
Total Carbon sequestered(tons)	242.07		997.12	
Top 3 major carbon sequestering species (tons)	*Ficus racemosa* L.	170.91	*Terminalia arjuna* (Roxb.) Wight & Arn.	860.99
	Canthium dicoccum (Gaertn.) Merr.	19.32	*Ficus religiosa* L.	96.87
	Elaeocarpus serratus L.	7.79	*Azadirachta indica* A. Juss.	22.21

Talakaveri Wildlife Sanctuary lies adjacent to *Brahmagiri* Wildlife Sanctuary which has managed to maintain two Intact Forest Landscapes (Reddy *et al.*,2017)this proximitycreates a continuous protected area which witness wide array of tree species. The total biomass recorded in the tree speciesat*Talakaveri* was132037.37 Kg. The most common tree species documented was *Canthium dicoccum* (Gaertn.) Merr. (47 trees) followed by *Glochidion zeylanicum* (Gaertn.) A.Juss. (21 trees) and *Litsea floribunda* (Bl.) Gamble (12 trees). The largest DBH was recorded for *Canthium dicoccum* (Gaertn.) Merr.measuring 940.60 cm followed by*Ficus racemosa* L. and *Glochidion zeylanicum* (Gaertn.) A.Juss. measuring 596.19 cm and 300.17 cm respectively. The total carbon sequestered by the documented riparian trees in *Talakaveri* was 242.07 tons.(Table 2)

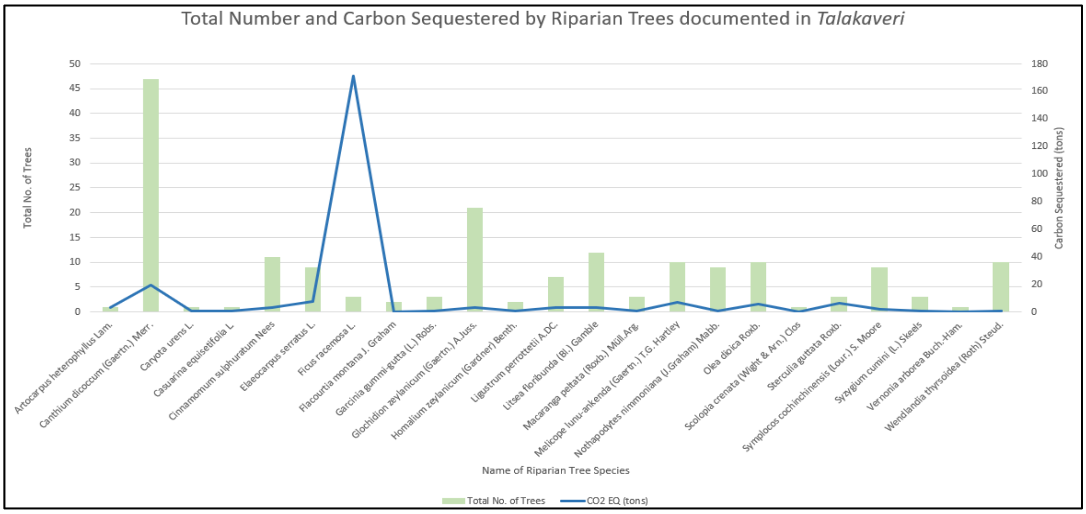

Figure 1 Graphical representation of Total Number and Carbon Sequestered by Riparian Trees documented in Talakaveri

In *Muthathi* (CWS)the landscape was mainly dominated by *Terminalia arjuna* (Roxb.) Wight & Arn.(21 trees).The total biomass recorded in the tree species at *Muthathi* was 543883 Kg. The second most common species is *Syzygium cumini* (L.) Skeels, with 19 trees, followed by *Azadirachta indica* A. Juss., which accounts for 8 trees. The largest DBH was recorded for *Terminalia arjuna* (Roxb.) Wight & Arn. Measuring 3172.91 cm followed by *Syzygium cumini* (L.) Skeels and *Ficus religiosa* L. measuring 391.52 cm and 368.92 cm respectively. The total carbon sequestered by the documented riparian trees in *Muthathi* was 997.12 tons out of which 860.99 tons is sequestered by *Terminalia arjuna* (Roxb.) Wight & Arn. demonstrating its importance as the keystone species of the region. (Nagaraja *et al.*, 2014). (Table 3)

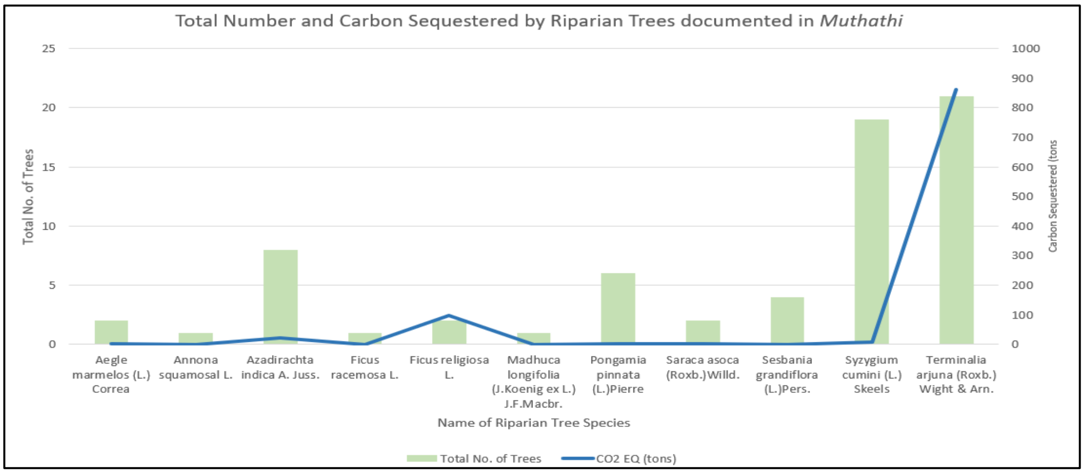

Figure 2Graphical representation of Total Number and carbon sequestered by Riparian Trees documented in Muthathi

Table 2CO_2 Eq of Riparian Tree Species in Talakaveri(tons)

Sr. No	Name of Tree Species	Total No. of Trees	Total DBH	AGB	BGB	TB	Carbon Content	CO_2 EQ (Kg)	CO_2 EQ (tons)
1	*Artocarpus heterophyllus* Lam.	1	51.57	1370.54	356.34	1726.88	863.44	3165.94	3.17
2	*Canthium dicoccum* (Gaertn.) Merr.	47	940.60	8324.26	2164.31	10488.56	5244.28	19229.03	19.23
3	*Caryota urens* L.	1	23.55	210.03	54.61	264.64	132.32	485.17	0.49

4	*Casuarina equisetifolia* L.	1	28.33	334.74	87.03	421.77	210.89	773.25	0.77
5	*Cinnamomum sulphuratum* Nees	11	212.95	1472.10	382.75	1854.85	927.42	3400.55	3.40
6	*Elaeocarpus serratus* L.	9	259.10	3373.51	877.11	4250.62	2125.31	7792.80	7.79
7	*Ficus racemosa* L.	3	596.19	73985.80	19236.31	93222.10	46611.05	170907.19	170.91
8	*Flacourtia montana* J. Graham	2	19.74	38.58	10.03	48.61	24.31	89.13	0.09
9	*Garcinia gummi-gutta* (L.) Robs.	3	49.97	291.02	75.67	366.69	183.34	672.26	0.67
10	*Glochidion zeylanicum* (Gaertn.) A.Juss.	21	300.17	1395.48	362.82	1758.30	879.15	3223.56	3.22
11	*Homalium zeylanicum* (Gardner) Benth.	2	39.79	270.36	70.29	340.65	170.33	624.53	0.62
12	*Ligustrum perrottetii* A.DC.	7	151.83	1290.09	335.42	1625.51	812.76	2980.11	2.98
13	*Litsea floribunda* (Bl.) Gamble	12	219.63	1415.46	368.02	1783.48	891.74	3269.71	3.27
14	*Macaranga peltata* (Roxb.) Müll.Arg.	3	60.80	427.10	111.04	538.14	269.07	986.59	0.99
15	*Melicope lunu-ankenda* (Gaertn.) T.G. Hartley	10	248.60	3129.61	813.70	3943.30	1971.65	7229.39	7.23
16	*Nothapodytes nimmoniana* (J.Graham) Mabb.	9	107.27	325.77	84.70	410.48	205.24	752.54	0.75
17	*Olea dioica* Roxb.	10	228.86	2442.43	635.03	3077.46	1538.73	5642.00	5.64
18	*Scolopia crenata* (Wight & Arn.) Clos	1	21.65	168.56	43.82	212.38	106.19	389.37	0.39
19	*Sterculia guttata* Roxb.	3	117.77	2810.97	730.85	3541.82	1770.91	6493.35	6.49
20	*Symplocos cochinchinensis* (Lour.) S. Moore	9	142.28	884.09	229.86	1113.95	556.98	2042.25	2.04
21	*Syzygium cumini* (L.) Skeels	3	55.07	341.40	88.76	430.16	215.08	788.63	0.79
22	*Vernonia arborea* Buch.-Ham.	1	14.32	54.11	14.07	68.18	34.09	124.99	0.12
23	*Wendlandia thyrsoidea* (Roth) Steud.	10	119.37	435.58	113.25	548.83	274.41	1006.18	1.01
	Total	179	4009.421951	104791.5608	27245.80581	132037.3666	66018.68331	242068.5055	242.0685055

Table 3 CO_2Eq of Riparian Tree Species in Muthathi(tons)

Sr. No	Name of Tree Species	Total No. of Trees	Total DBH	AGB	BGB	TB	Carbon Content	CO_2 EQ (Kg)	CO_2 EQ (tons)
1	*Aegle marmelos* (L.) Correa	2	62.39	848.11	220.51	1068.62	534.31	1959.13	1.96
2	*Annona squamosal* L.	1	21.96	175.14	45.54	220.67	110.34	404.56	0.40
3	*Azadirachta indica* A. Juss.	8	323.40	9615.99	2500.16	12116.15	6058.07	22212.94	22.21
4	*Ficus racemosa* L.	1	24.19	224.92	58.48	283.40	141.70	519.57	0.52
5	*Ficus religiosa* L.	2	368.92	41933.32	10902.66	52835.99	26417.99	96865.98	96.87
6	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	1	26.10	272.80	70.93	343.73	171.87	630.18	0.63
7	*Pongamia pinnata* (L.)Pierre	6	151.20	1539.81	400.35	1940.16	970.08	3556.97	3.56

8	*Saraca asoca* (Roxb.)Willd.	2	55.70	642.14	166.96	809.09	404.55	1483.33	1.48
9	*Sesbania grandiflora* (L.)Pers.	4	33.10	51.75	13.45	65.20	32.60	119.54	0.12
10	*Syzygium cumini* (L.) Skeels	19	391.52	3625.76	942.70	4568.46	2284.23	8375.50	8.38
11	*Terminalia arjuna* (Roxb.) Wight & Arn.	21	3172.91	372723.27	96908.05	469631.32	234815.66	860990.75	860.99
	Total	67	4631.40	431653.01	112229.78	543882.79	271941.39	997118.44	997.12

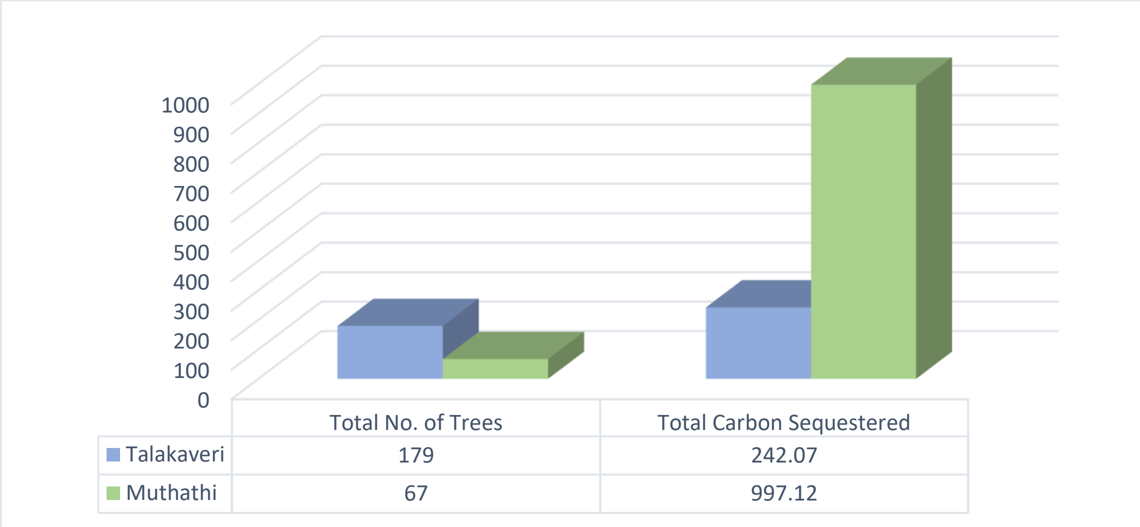

Figure 3 Graphical representation of Comparison between Total Number and Carbon Sequestered by Riparian Trees documented in Talakaveri and Muthathi

CONCLUSION

Riparian trees and the ecosystems they inhabit are intricately linked to the broader climatic and environmental conditions within landscapes. Climate change poses significant challenges to these ecosystems through both direct climatic stimuli and indirect effects mediated by changes in surrounding terrestrial and aquatic environments. Although riparian trees are endowed with remarkable adaptive traits that allow them to navigate and endure fluctuating conditions, their ecosystems' capacity to adapt to climate change is constrained by various factors, including non-climatic threats and pervasive human activity. Addressing these challenges requires a holistic approach to conservation and management that prioritizes maintaining connectivity and environmental heterogeneity, while also mitigating the overarching impacts of climate change to ensure the resilience and continuity of these critical ecosystems.

The Riparian Trees of CRB stand strong in the face of climate crises through their capacity for sequestering carbon and other vital ecosystem services.Their existence is a testament to the fragile equilibrium that sustains life, an equilibrium now threatened by the accelerating pace of environmental change.The study highlights notable differences between carbon sequestration potential of riparian trees in *Talacauvery* and *Muthathi*, while *Talakaveri* hosts diverse range of species and exhibits higher species richness, *Muthathi* despite hosting fewer species documents higher carbon sequestration potential (Fig. 3) primarily due to the presence of *Terminalia arjuna* (Roxb.) Wight & Arn., emphasizing on the need to conserve the keystone species.It is important to create an awareness amongst the tourists visiting these sites on the ecosystem services provided by the riparian trees amongst, to help them develop Environmentally Responsible Behaviour (Ma. *et al.*, 2018) which eventually leads to sustainable tourism practices.

The Riparian Trees of CRB are testament to the resilience of river Cauvery, nurturing the life it creates. Safeguarding and investing in restoration of Riparian Forest hold substantial potential to address the urgent climate change mitigation goals and preservation of biodiversity and ecosystem services. (Dybala*et al.*, 2019). As stated by UN Secretary-General António Guterres "the climate emergency is a race we are losing, but it is a race we can win." thus it becomes a paramount task to protect these Riparian Trees and save us from getting submerged in our avarice.

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