__Original Research Article__

Carbon Sequestration Potential of Trees in Urban Vegetation Islands: A Case Study

Abstract

Increasing levels of atmospheric carbon dioxide (CO_2) and other “greenhouse” gases contribute to an increase in atmospheric temperature. Trees act as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. The current study focuses on the contribution of vegetation within Janki Devi Bajaj Government Girls College, Kota towards carbon sequestration potential and climate regulation. Non-destructive method of biomass estimation was used to measure the GBH of individual trees on the campus. The present study enumerated a total of 849 trees belonging to 43 tree species on the campus. The most dominant species was *Syzygiumcumini*(L.) Skeels with a total of 163 trees followed by *Phoenix sylvestris*(L.) Roxb (121 trees) and *Eucalyptus obliqua*L'Her (97 trees). The above-ground biomass (AGB) and below-ground biomass (BGB) of all the trees on the campus are equivalent to 373937 kg and 56090.54 kg, respectively. The total biomass accumulated is 430027.5 kg and the total carbon content of the campus trees is equal to 206733 kg. The total carbon sequestered by all the trees in a year is 713.14 tons. In other words, on average carbon sequestered by an individual tree on the campus is 840.92 kg/year or 0.84 tons/year.The biomass of the tree species has a wider impact on carbon storage and sequestration in comparison to other structural parameters.

Keywords: Sequestration**,** Biomass, Climate change, Carbon.

Introduction

Rapid urbanization has become a major cause of climate change, driving land use change, habitat lossresultingdecline in biodiversity, and pollution both within and outside the city **(Satterthwaite et al., 2010).**A major part of this pollution is contributed by increasing levels of atmospheric carbon dioxide and other greenhouse gases. Reduction in CO_2 concentrations in the atmosphere can be achieved by increasing the rate of removal of $CO_2$by the trees through carbon sequestration which can decrease the atmospheric CO_2 naturally **(IDFC, 2010).**Recently urban forests & urban green spaces received much attention in combating climate change and reducing biodiversity loss. These urban forests(trees in gardens, parks, and along the streets, roads, canals, etc.) contribute to verdancy in the city **(Ugle et al., 2010),** play an important role in biodiversity conservation **(Hillary et al., 2002)**and areimportant in carbon sequestration **(Tiwari and Singh, 1987; FSI, 2009).** These spaces provide a variety of ecosystem services such as improving air quality **(Singh *et al*., 2018)**by reducing air pollution **(Nowak *et al*. 2006),**may represent an important carbon reservoir through carbon sequestration **(Shah &Gavali, 2017) and** thusplay a very important role in limiting the city's carbon footprint **(Strohbach*et al*., 2012).** The vegetation and soil of a greenspace can not only sequester carbon, contributing directly to a reduction in atmospheric CO_2 concentration but also affect the carbon balance indirectly, through their effects on the urban energy balance and thus on CO_2 emissions related to energy use **(Churkina, 2016; Akbari *et al*., 2001).**Unfortunately, these areas are also being sacrificed in the race for urbanization; there is an urgent need to restore these green patches. Restoration must be carefully planned as sometimes we introduce species that are harmful to the native flora; so, we must use some restoration strategies like those suggested by **Dadhich and Jaiswal, (2022)**and **Dadhich et al., (2023).**

According to **IPCC (2006),** the major five carbon pools of a terrestrial ecosystem involving biomass are above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter. Trees are important sinks for atmospheric carbon i.e., carbon dioxide, since 50% of their standing biomass is carbon itself **(Ravindranath*et al*., 1997).** Trees and other types of vegetation provide significant local cooling by transpiration, and provision of habitats for flora and fauna **(Nowak and Crane, 2002;Wilby and Perry, 2006)**.The carbon assimilated by trees is retained for a longer duration with little leakage into the atmosphere. Annual rates of carbon sequestration largely depend on the tree's size at maturity, life span, and growth rates **(Nowak, 2000).** After the trees die, the biomass either enters the food chain or the soil as soil carbon (**Suryavanshi*et al*., 2014).**

Though the importance of forested areas in carbon sequestration has been well established and documented, few attempts have been made to address the potential of trees in carbon sequestration in urban cities. Generally, in developing countries, where urbanization is most rapid, the collection of data is very important to represent the correct status of urban vegetation. It is important to study the carbon sequestration potential of urban centers so as to understand and highlight the role of urban green spaces in offsetting carbon emissions at a local level. Large educational institute campuses provide large areas for urban tree plantations that can be a potential solution for climate change mitigation through carbon storage and carbon sequestration.

There are various studies that highlightthe importance of educational institutes in carbon stocking (**Gavali and Shaikh, 2016;Marak and Khare, 2017; Nandini*et al*., 2009; Pragasan*et al*., 2013;Ahmedin*et al*., 2013; Das & Mukherjee, 2015; Ganguly*et al*., 2017; Kour and Sharma, 2016 and Saral*et al*., 2017).**The present study was conducted with the objective of collecting adequate data on urban vegetation playing an important role in carbon storage and sequestration in a prominent educational institute.

Study Area

The study was conducted in the Janki Devi Bajaj government girl's college, Kota. The campus of this college was established in 1958 and is the largest girl's college in the Hadoti regionof Rajasthan. The campus covers a total area of 57.47 acres. The geographical location of this college is 25.179324° N and 75.853915° E. Kota is situated in southeastern Rajasthan along the bank of river Chambal.

The city experiences cold winters and warm summers, with a temperature ranging from a maximum of 48 °C to a minimum of 9°C. It receives very little rainfall throughout the year with an average of around 728 mm per year. The city has witnessed extensive urbanization over the years, with a number of high-rise buildings, corporations, and industries.

Figure 1: Satellite map of JDB Govt. Girls College campus showing dense vegetation.

Material and methods:

Field data of tree species on the campus was recorded. Identification of trees up to species level was done through visual observation and verified bythe flora of**Singh & Shetty, (1987 &1991).**

Non-destructive method of biomass estimation was used to measure the GBH of individual trees on the campus. The girth of individual trees at breast height (1.37 m) was enumerated. The girth was measured using measuring tape. Above-ground biomass (AGB) andbelow-ground biomass (BGB) were calculated with the help of field measures of diameter at breast height (DBH) of the trees using allometric equations (**MacDicken, 1997).**The below given equation is applicable for dry climates with annual rainfall <1500mm; which makes it ideal for the study area where annual rainfall is 728mm.

Above ground biomass (AGB): $34.4703 - 8.0671D + 0.6589D^2$

Where, D= DBH (cm.)

Below ground biomass (BGB) =AGB × (15/100)

Total biomass = AGB+BGB

Carbon Content = 0.5×total biomass

Carbon equivalent = (Carbon content×44)/12

Observation & Result

The present study enumerated a total of 849 trees belonging to 43 tree species on the campus. The most dominant species was *Syzygiumcumini*(L.) Skeels with a total of 163 trees followed by *Phoenix sylvestris*(L.) Roxb (121 trees) and *Eucalyptus obliqua*L'Her (97 trees). Fabaceae was found to be the most species-rich family with 11 species and all other families were represented by 3 or <3 species.Family Fabaceae represents the most dominant family due to its high adaptability **(Rundel, 1989)**; it is also verified by the work of **Jaiswal& Dadhich (2010),Dadhich and Jaiswal(2023) and Malav and Jaiswal(2023).** In terms of density and total individuals, Myrtaceae shows the highest density followed by Fabaceae and Areceae whereas in terms of Total biomass and C equivalent, Family Myrtaceae is followed by Moraceae and Fabaceae. The above-ground biomass (AGB) and below-ground biomass (BGB) of all the trees on the campus are equivalent to 373937 kg and 56090.54 kg respectively. The total biomass accumulated is 430027.5 kg and the total carbon content of the campus trees is equal to 215013.8 kg. The total carbon sequestered by all the trees in a year is 713.94 tons. In other words, on average carbon sequestered by an individual tree on the campus is 840.919 kg/year or 0.84 tons/year.

Table 1: Data of Tree species in Janki Devi Bajaj Government Girls College, Kota.

S.N.	Tree species	Family	No. of trees	AGB (kg)	BGA (kg)	Total Biomass (kg)	Carbon Content (kg)	Carbon Equivalent	Carbon equivalent(Tons)
1	*Acacia nilotica*(L.) Willd. Ex Delile	Fabaceae	85	8744.1	1311.62	10055.72	5027.86	18435.48	18.21
2	*Aegle marmelos*(L.) Correa	Rutaceae	4	966.69	145.0035	1111.694	555.8468	2038.105	2.04
3	*Albizialebbeck*L. Benth.	Fabaceae	5	1401.94	210.291	1612.231	806.1155	2955.757	2.95
4	*Alstoniascholaris*(L.) R. Br.	Apocynaceae	7	673.92	101.088	775.008	387.504	1420.848	1.42
5	*Azadirachtaindica*A. Juss.	Meliaceae	20	16153.02	2422.953	18575.97	9287.987	34055.95	34.05
6	*Bauhinia variegata*(L.) Benth.	Fabaceae	14	2745.23	411.7845	3157.015	1578.507	5787.86	5.79
7	*Bombaxceiba*L.	Malvaceae	6	120.26	18.03	138.29	69.15	253.54	0.28
8	*Caryotaurens*L.	Arecaceae	7	701.2	105.18	806.38	403.19	1478.363	1.48
9	*Cassia fistula* L.	Fabaceae	4	452.47	67.8705	520.3405	260.1703	953.9576	0.95
10	*Cassia siamea*Lam.	Fabaceae	13	2482.6	372.39	2854.99	1427.495	5234.148	5.23
11	*Citrus limon*(L.) Burm. f.	Rutaceae	3	47.36	7.104	54.464	27.232	99.85067	0.09
12	*Collistemoncitrinus*(Curtis) Skeels [es]	Myrtaceae	9	4504.09	675.6135	5179.704	2589.852	9496.123	9.5
13	*Cordiadichotoma*G.Forst.	Boraginaceae	8	572.41	85.8615	658.2715	329.1358	1206.831	1.2
14	*Cratevareligiosa*G.Forst.	Capparaceae	3	319.66	47.949	367.609	183.8045	673.9498	0.67

15	*Dalbergiasissoo*Roxb.	Fabaceae	25	4591.4	688.71	5280.11	2640.055	9680.202	9.68
16	*Delonixregia*(Boj. Ex Hook.) Raf.	Fabaceae	6	1156.21	173.4315	1329.642	664.8208	2437.676	2.44
17	*Eucalyptus obliqua*L'Her.	Myrtaceae	97	66190.69	9928.604	76119.29	38059.65	139552	139.55
18	*Ficusbenghalensis*L.	Moraceae	11	49890.15	7483.523	57373.67	28686.84	105185.1	105.18
19	*Ficusreligiosa*L.	Moraceae	13	15839.77	2375.966	18215.74	9107.868	33395.52	33.39
20	*Guazumaulmifolia*Lam.	Malvaceae	8	543.31	81.4965	624.8065	312.4033	1145.479	1.14
21	*Holopteleaintegrifolia*(Roxb.) Planch.	Ulmaceae	12	1447.46	217.119	1664.579	832.2895	3051.728	3.05
22	*Jatropha curcus*L.	Euphorbiaceae	5	54.21	8.1315	62.3415	31.17075	114.2928	0.11
23	*Lagerstroemia indica*L.	Lythraceae	6	939.38	140.907	1080.287	540.1435	1980.526	1.98
24	*Mangiferaindica*L.	Anacardiaceae	7	8739.92	1310.988	10050.91	5025.454	18426.66	18.43
25	*Manikarahexandra*(Roxb.) Dubard	Sapotaceae	3	53.56	8.034	61.594	30.797	112.9223	0.11
26	*Mitragynaparvifolia*(Roxb.) Korth	Rubiaceae	32	5965.94	894.891	6860.831	3430.416	12578.19	12.58
27	*Morus alba* L.	Moraceae	2	22.84	3.426	26.266	13.133	48.15433	0.04
28	*Neolamarckiacadamba*(Roxb.) Bosser	Rubiaceae	5	1232.56	184.884	1417.444	708.722	2598.647	2.6
29	*Peltophorumpterocarpum*(DC.) K.Heyne	Fabaceae	29	14847.91	2227.187	17075.1	8537.548	31304.34	31.3
30	*Phoenix sylvestris*(L.) Roxb	Arecaceae	121	44048.44	6607.266	50655.71	25327.85	92868.79	48.88

31	*Phyllanthusemblica*L.	Phyllanthaceae	4	778.15	116.7225	894.8725	447.4363	1640.6	1.64
32	*Phyllanthusreticulatus*Poir.	Phyllanthaceae	2	44.62	6.693	51.313	25.6565	94.07383	0.06
33	*Pithecellobiumdulce*(Roxb) Benth.	Fabaceae	4	54.41	8.1615	62.5715	31.28575	114.7144	0.11
34	*Plumeriapudica*Jacq.	Apocynaceae	7	97.77	14.6655	112.4355	56.21775	206.1318	0.21
35	*Polyalthialongifolia*(Sonn.) Wall.	Annonaceae	16	186.5	27.975	214.475	107.2375	393.2042	0.39
36	*Pongamiapinnata*(L.) Pierre	Fabaceae	11	1582.68	237.402	1820.082	910.041	3336.817	3.34
37	*Ricinuscommunis*L.	Euphorbiaceae	44	788.79	118.3185	907.1085	453.5543	1663.032	1.14
38	*Streculiafoetida*L.	Malvaceae	7	1109.89	166.4835	1276.374	638.1868	2340.018	2.34
39	*Syzygiumcumini*(L.) Skeels.	Myrtaceae	163	102156.6	15323.49	117480.1	50881.56	215380.2	186.56
40	*Tabernaemontanadivaricata*R. Br. EcRoem. &Schult.	Apocynaceae	5	75.9	11.385	87.285	43.6425	160.0225	0.16
41	*Tamarindusindica*L.	Fabaceae	3	8242.31	1236.347	9478.657	4739.328	17377.54	17.38
42	*Tectonagrandis*L.f.	Lamiaceae	5	1770.83	265.6245	2036.455	1018.227	3733.5	3.73
43	*Ziziphusmauritiana*Lam.	Rhamnaceae	8	1599.82	239.973	1839.793	919.8965	3372.954	3.37
			849	**373937**	**56090.54**	**430027.5**	**215013.8**	**788383.8**	**713.94**

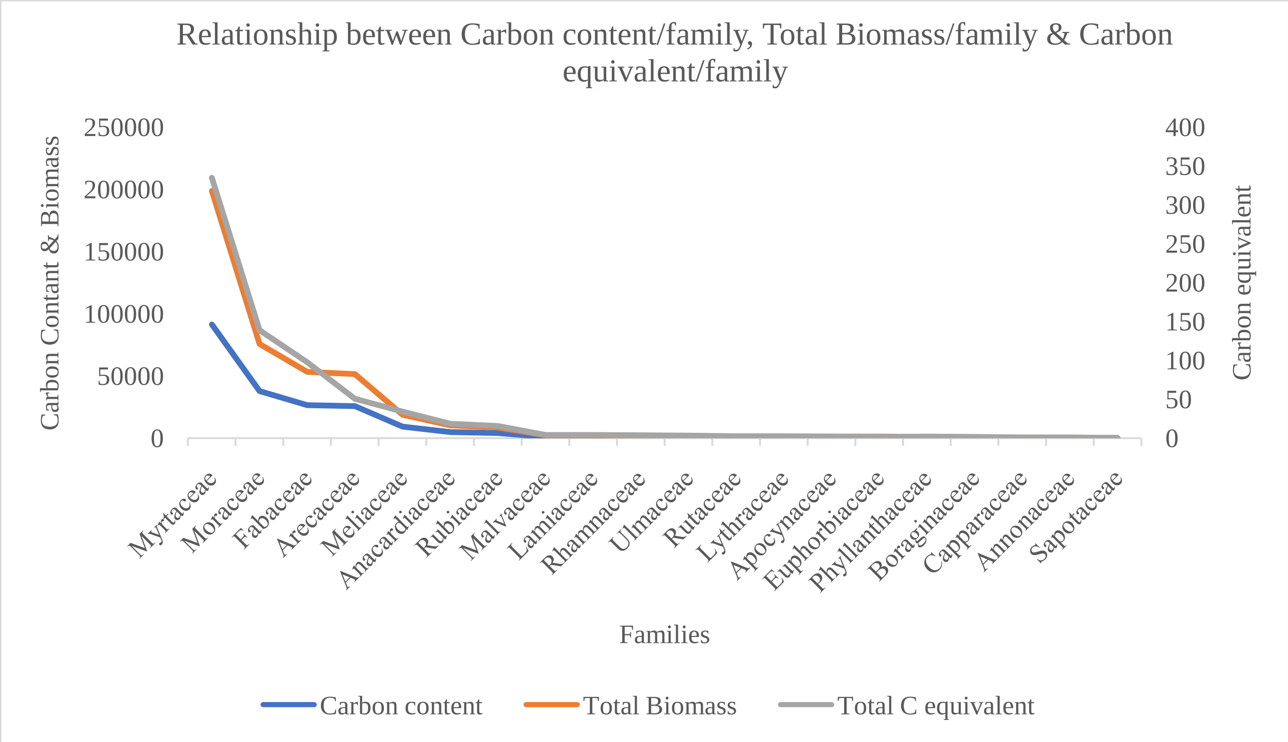

Figure 2: Relationship between number of plants per family, biomass/family, and Carbon equivalent/family in the sampled area.

Figure 2 shows that Carbon equivalent, Carbon content, and Biomass follow the same trend, which means they have the same correlation between these parameters. Families having higher biomass have higher carbon content as well as carbon equivalent. Whereas species richness, density, and C equivalent per family are not correlated (Figure 3). Families having higher species richness and density (Fabaceae, Aracaceae) have lower carbon equivalents and family Moraceae and Meliaceae have higher carbon equivalents although have lower species richness and density. These results show that the diameter of the tree has the most significant effect on the stored carbon rather than density and species richness.

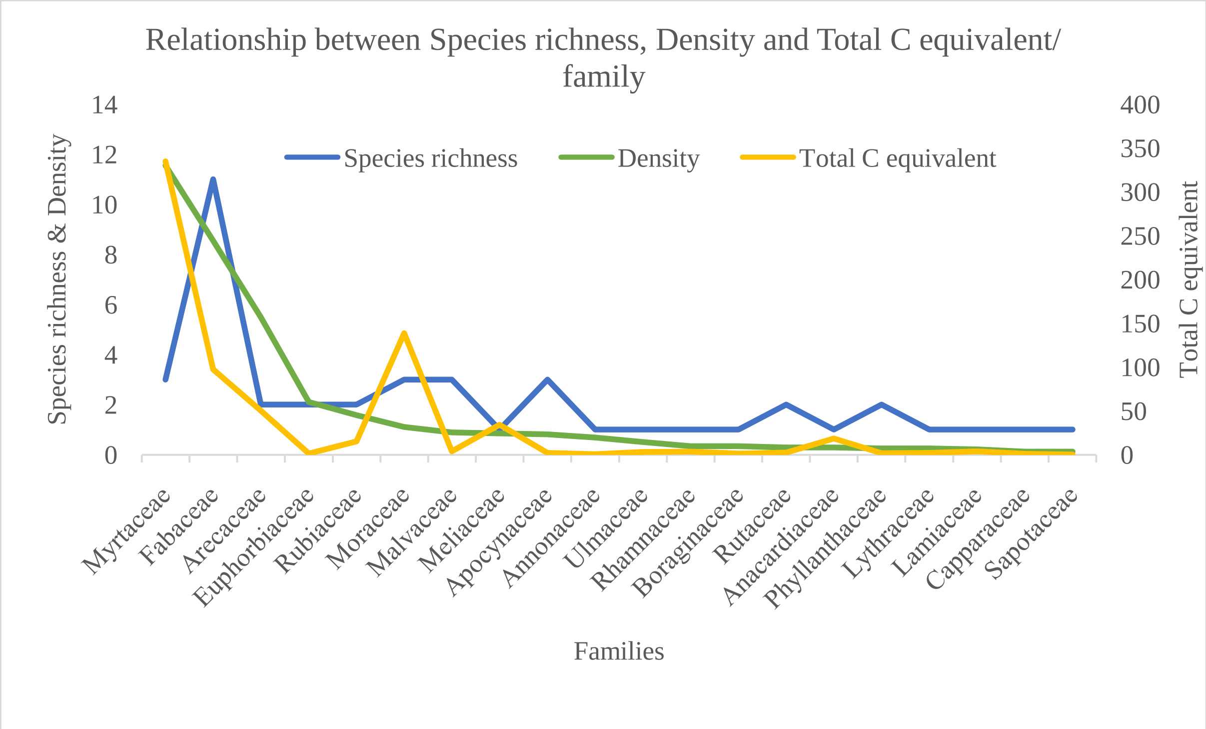

Figure 3: Relationship between Species richness, Density, and Total C equivalent/ family in the study area.

Fabaceae, Myrtaceae, Moraceae, Malvaceae, and Apocynacaeaaccount for almost 50% of the species richness, Fabaceae alone accounts for 1/4th of the species richness. In terms of the number of individuals, Myrtaceaehas the highest number of plants as well as density followed by Fabaceae and Arecaceae in both the number of species and density. Myrtaceae has maximum Carbon content, Carbon equivalent as well as Total biomass followed by Moraceaeand Fabaceae. Results of the study show that biomass has a strong correlation to the potential stored carbon. Several other parameters; tree diameter, stands density, and tree species diversity correlated to increasing tree biomass hence to the increasing of stored carbon **(Rahayu*et al.*, 2007; Tresnawan and Rosalina, 2002; Supendi, 2007; Mawazin and Suhendi, 2008).**

Discussion:

Urban cities are responsible for 75% of global CO_2 emissions**(UNEP report: Cities & Climate Change)**. Urban vegetation can be seen as a carbon absorber if the total amount of CO_2 absorbed during photosynthesis is higher than the CO_2 released during respiration.The role of forested areas in carbon sequestration is well documented **(FSI, 2009; Tiwari and Singh, 1987)**. The development of Urban Forests will contribute to India's decision to sequester 2.5 to 3 billion tonnes of carbon dioxide equivalent in the country's forests **(MoE,**

2020). In recent years, preserving and maintaining urban forests and vegetation hasrecognized its importance in ecological, social, and aesthetic values.

Biomass is an important indicator of carbon sequestration and a tool to access the structural and functional attributes of trees because approximately 50% of the dry biomass of trees comprises Carbon **(Ravindranath*et al*., 1997;Montagnini and Porras, 1998; Losi*etal*., 2003; Montagu *et al*., 2005).** Results of the present study indicate that the vegetation of the campus is species-rich, represented by 43 tree species. In urban forests large number of species within very small areas indicates rich biodiversity **(Gupta *et al*., 2008).** Though the college campus has a tree density of 0.004 trees/sqm but contributes significantly to Carbon sequestration in urban areas.

Nowak, (1994) indicated that 600 trees in the tropics could sequester up to 15 tonnes of CO2 annually and 40 trees will sequester one tonne of CO2 each year. Usually, urban forests have relatively low tree cover, even though they can store comparatively lesser Carbon/hectare (25.1tC/ha) than forest stands (53.5tC/ha). Urban forests due to faster growth rate and a greater proportion of larger trees in urban areas, Carbon storage by urban trees and gross carbon sequestration may be greater than in forest stands on a per unit tree cover basis **(Nowak, 1994).** Due to more open forest structure differences in tree diameter distributions between urban and forest areas. This may be the reason that individual urban trees, on average, contain approximately four times more C than individual trees in forest stands **(Nowak and Crane, 2002).**CO_2 stored in biomass by the urban forest amounted to about 0.2 million tons **(Yang *et al*., 2005).**

To fulfill the agenda of SDG 2030, **(SDG, UN, 2015)**institutions of higher education have a significant role to play in a way to develop small vegetation islands which can contribute to atmospheric Carbon sequestration. Thus, green campuses ofeducational institutescan contribute towards sustainable development goals related to climate actions through regulating services provided by the forest and prevention of terrestrial life forms through the conservation of biodiversity within it. This work will help build up the baseline information about biodiversity within the urban forest islands and the role of thesevegetation in regulating the local climate through carbon sequestration.

Conclusion:

The results of the study illuminate the value of urban trees in mitigating the impacts of global warming at a local level. Vegetation of education institutes have an important role in expanding their green cover so as to act as local carbon sinks. The study acts as a baseline for future assessments of the campus carbon sink. Such education institutes can model themselves as agents of fulfilling the agenda of SDG 2030.Urban green islands are likely to have a wider impact on biomass in carbon storage and sequestration in comparison to other structural parameters like species richness or density.Thus, the amount of potential carbon storage is positively influenced by increasing biomass.

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