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Carbon Sequestration Potential of Tree Species: A Case Study from Gurukula Kangri University, Haridwar, India

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ABSTRACT

Amidst the severity of altering climatic conditions primarily induced by anthropogenic actions, tree based carbon sequestration is widely accepted as a nature based, cost effective alternative for mitigating climate challenges particularly in semi urban and urban regions. Nested in Himalayan foothills Gurukula Kangri University, Uttarakhand Campus is an important urban green space providing essential ecosystem services. The present study aims to establish baseline data on tree diversity within the campus and to quantify their carbon storage capacity. A total 72 tree species, dominated by native (72%) representing 31 families, were documented. The assessment of biomass and carbon sequestration potential is conducted using allometric equations in conjunction with IPCC recommended methodology. The above-ground and below-ground biomass of trees on the campus were estimated 1653919 kg and 167189.5 kg, respectively, yielding a total biomass of 1821108.5 kg. The annual carbon sequestration potential of all trees was estimated at 3332.32 tons. The current study underscores the importance of institutional urban spaces in combating climatic crises acting as future carbon sink, emphasizing more strategic planning and execution in establishing green cover in cities.

Keywords Above ground biomass, Allometric equations, Below ground biomass, Carbon sequestration, Urban green space.

INTRODUCTION

Carbon is one of the essential components of living beings. Many natural carbon stocks are present on earth in various forms such as fossil fuel depositions, ocean and atmosphere. Increased vehicle numbers and developmental activities show a direct correlation with pollutant concentration in environment, especially carbon dioxide. In the preindustrial era, the mean carbon dioxide level was 280 ppm as of December 2024, the mean carbon dioxide level was 407 ppm (NOAA 2024). Carbon dioxide is a greenhouse gas that contributes significantly to global warming (Yoro

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and Daramola 2020). Carbon sequestration refers to the uptake of atmospheric CO_2 and its subsequent storage in land based ecosystems. Carbon is sequestrated across various ecosystems including agricultural lands, forests, grassland, wetlands, rocks, sediments and forest land. Soil, seawater, herbs, shrubs and plants play a vital role in regulating atmospheric CO_2 by absorbing and storing it (Lal 2007).

Terrestrial vegetation is a crucial component for maintaining and regulating carbon concentration in the environment. Mostly terrestrial carbon storage occurs in roots, foliage, branches and trunks of trees, often called as biomass (Watson *et al.* 2000, Suryawanshi *et al.* 2014). Most crucial component of sink and source of carbon are terrestrial soil and vegetation. During photosynthesis, plants fix atmospheric carbon dioxide and storing the excess CO_2 as biomass, and consequently, trees functions as important carbon dioxide (Prentice *et al.* 2001). Although all autotrophs perform photosynthesis and convert CO_2 into biomass, among them, trees are considered major sponges or sinks of carbon.

Biomass constitutes a crucial component of the global carbon cycle, playing a significant role in carbon sequestration, and mitigating imbalances arising from with land use changes and greenhouse gas emissions (Chavan and Rasal 2010). As trees develop and grows, their biomass also increases, they perform photosynthesis and absorb and store CO_2 in growing plant tissues (Patil and Kumar 2017, Sharma *et al.* 2020). The carbon assimilated by trees is retained for longer periods with minimal loss. However, the annual rate of carbon sequestration is influenced by factors such as life span, growth rate, and tree size. After the death of a tree, the biomass can enter the soil or in the food chain and again become part of the environment (DeAngelis 2012).

Currently, Governments and Municipal authorities are actively promoting the expansion of Urban Green Spaces (UGS) and urban forests within cities. Urban Green Spaces (UGS) encompass all urban areas covered with vegetation, including street trees, gardens, parks, and landscaped areas around buildings. These spaces provide a range of ecosystem services, including regulating services (such as microclimate regulation, air purification, water cycle regulation, and noise mitigation), provisioning services (including food, green cuttings and timber), and cultural services (Roland *et al.* 2023). UGS also have the potential to mitigate climate change impacts by influencing local climate, the carbon cycle, and overall energy use (Vasagadekar *et al.* 2023). The potential of trees in urban cities for carbon sequestration has not received much attention, even though the value of forest regions in this regard has been well-established and documented. Therefore, assessing the carbon sequestration potential of urban green spaces is crucial for understanding their contribution to reducing local carbon emissions. In light of this, the present study was conducted on the Campus of Gurukula Kangri University, Haridwar, with the primary objective of inventorying the tree species present and estimating their carbon sequestration potential.

MATERIALS AND METHODS

Study area

The present study was carried out in the Gurukula Kangri (DTBU), Haridwar (Main Campus), located in Haridwar, Uttarakhand. Gurukula Kangri University is one of the Oldest Universities in India, it was founded in 1902 by Swami Shraddhanandaji. The campus is spread over an area of 204.948 acres with a built-up area of 75885.71 sq meters (Fig. 1). Within the campus there is a mango orchard, teak plantation, medicinal garden, and many tree species are planted across the campus for the conservation of the native biodiversity from the Haridwar region. Haridwar has a hot sub-humid dry climate with 3 distinct seasons i.e. summer, rain and winter season. The annual temperature ranges from 6.1°C to 39.2°C. The average annual rainfall in Haridwar district is 1174.3 mm, out of which 84% is received during monsoon season and only 16% occurs during non-monsoon period (CGWB 2016).

Methodology

A non-destructive approach was employed to estimate the biomass of different tree species, facilitating an understanding of biomass variation across the campus and providing insights into forest ecology

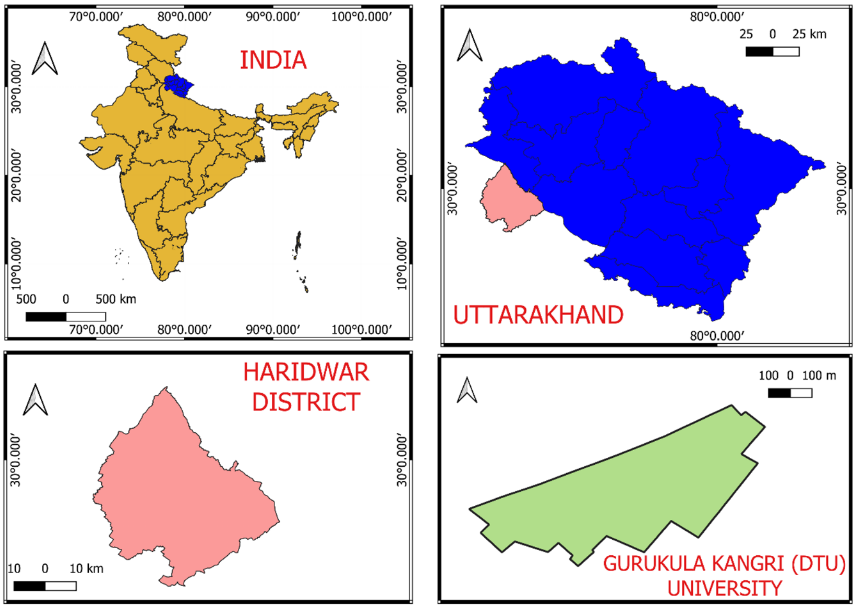

Fig. 1. Study area.

and management (Tak and Kakde 2020). The study was conducted during the winter season (November 2023–January 2024). Tree biomass was estimated using allometric equations based on measurements of diameter at breast height (DBH). Individual trees with a girth of ≥30 cm at breast height were enumerated. A measuring tape were used to record the tree girths. Plant species identification was carried out using local flora (Kanjilal 1928, Raizada 1976). The study focused exclusively on tree species, shrubs and herbs were not included.

Estimation of above-ground and below-ground biomass (AGB and BGB)

Biomass of trees was estimated using field measurements of diameter at breast height (DBH) and using appropriate allometric equations (MacDicken 1997). The below given equations is suitable for dry climates with annual rainfall below 1500 mm and is therefore applicable to Haridwar, where the average annual rainfall is 1174.3 mm (CGWB 2016, Pathak *et al.* 2020).

AGB = 34.4703 − 8.0671D + 0.6589 D_2 where D is the DBH (cm). D= Circumference/3.14

BGB = AGB × (15/100)

Estimation of total biomass (TB)

Total biomass = AGB + BGB

Estimation of carbon content

Carbon content = 0.5 × Total biomass

CO_2 equivalent is calculated using the below given equation:

CO_2 equivalent = (carbon content × 44)/12

CO_2 equivalent (tons) = CO_2 (equivalent)/1000

RESULTS AND DISCUSSION

Composition and diversity of campus trees

A total of 72 tree species were recorded from the Gurukula Kangri University Campus, comprising 70 angiosperms and 2 gymnosperms, distributed across 31 families (Table 1). The campus flora was dominated by the families Moraceae and Fabaceae (each

Table 1. CO_2 eq (tons) of tree species in Gurukula Kangri University.

Sl. No.	Scientific name	Common name	Native /exotic species	Total no. of trees	Average diameter (cm)	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 eq	CO_2 eq (tons)
1	*Mangifera indica*	Mango	N	231	52.32	506327.92	75949.18	582277.11	291138.556	1067508.04	1067.5
2	*Monoon longifolium*	Ashok	N	203	16.53	30866.08	4629.91	35495.99	17748	65075.99	65.07
3	*Tectona grandis*	Teak	N	101	19.78	14724.9	2208.73	16933.65	8466.82	31045.02	31.04
4	*Syzygium cumini*	Jamun	N	83	47.39	154452.04	23167.8064	177619.8491	88809.924	325636.39	325.63
5	*Psidium guajava*	Guava	E	46	15.84	5347.38	802.1	6149.48	3074.74	11274.05	11.27
6	*Alstonia scholaris*	Saptaparni	N	44	33.4	37839.18	5675.877	43515.06	21757.53	79777.6	79.77
7	*Eucalyptus sp.*		E	43	80.77	150760.7519	22614.11279	173374.8647	86687.43237	317853.9187	317.8
8	*Araucaria columnaris*	Kauri pine	E	42	19.6	6104.30	915.64	7019.95	3509.97	12869.91	12.86
9	*Broussonetia papyrifera*	Paper mulberry	N	40	14.19	2919.25	437.88	3357.14	1678.53	6154.77	6.15
10	*Azadirachta indica*	Neem	N	37	39.95	41199.57	6179.93	47379.51	23689.75	86862.44	86.86
11	*Phyllanthus emblica*	Awla	N	37	26.56	16796.47	2519.471362	19315.94711	9657.973554	35412.5697	35.41
12	*Grevillea robusta*	Silver oak	E	34	37.92	31058.7	4658.8	35717.5	17858.7	65482	65.84
13	*Melaleuca viminalis*	Bottle brush	E	22	18.95	3438.89	515.83	3954.72	1977.36	7250.32	7.2
14	*Bombax ceiba*	Semal	N	21	85.59	149482.5	22422.38	171904.9	85952.44	3151.59	315.15
15	*Terminalia bellirica*	Behera	N	19	30.11	10885.32	1632.79	12518.12	6259.06	22949.89	22.94

Table 1. Continued.

Sl. No.	Scientific name	Common name	Native /exotic species	Total no. of trees	Average diameter (cm)	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 eq	CO_2 eq (tons)
16	*Jacaranda mimosifolia*	Neeli gulmohar	E	18	24.6	6494.33	974.15	7468.48	3734.24	13692.22	13.69
17	*Thuja occidentalis*		E	17	39.8	14566.39	2184.95	16751.35	8375.67	30710.81	30.71
18	*Delonix regia*	Gulmohar	E	14	26.78	6398.72	959.8	7358.53	3679.27	13490.65	13.49
19	*Ficus religiosa*	Peepal	N	13	70.97	63922.45	9588.367	73510.81	36755.41	134769.8	134.76
20	*Morus alba*	Shahtoot	N	12	43.59	16141.32	2421.19	18562.52	9281.26	34031.29.	34.03
21	*Terminalia arjuna*	Arjuna	N	12	33.65	9748.57	1462.28	11210.86	5605.43	20553.24	20.55
22	*Artocarpus lacucha*	Lakucha	N	11	87.08	54951.19	8242.67	63913.87	31596.93	115855.4	115.85
23	*Melia azedarach*	Bakain	N	11	37.03	9948.24	1492.23	11440.47	5720.23	20974.2	20.97
24	*Ficus racemosa*	Goolar	N	10	72.56	46394.74	6959.21	53353.95	26676.97	97815.57	97.81
25	*Cassia fistula*	Amaltas	N	8	29.05	3757.99	563.69	4321.69	2160.84	7923.1	7.92
26	*Cinnamomum camphora*	Kapor	E	7	42.33	18551.7	2782.75	21334.47	10667.23	39113.19	39.11
27	*Neolamarckia cadamba*	Kadamba	N	7	32.49	80594.95	7140.37	8211.426249	4105.713125	15054.28146	15.05
28	*Toona ciliata*	Toon	N	7	35.31	5826.28	873.94	6700.23	3350.11	12283.76	12.28
29	*Pterospermum acerifolium*	Kanak champa	N	7	34.57	3935.71	590.35	4526.07	2263.03	8927.79	8.29

Table 1. Continued.

Sl. No.	Scientific name	Common name	Native /exotic species	Total no. of trees	Average diameter (cm)	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 eq	CO_2 eq (tons)
30	*Bergera koenigii*	Kari patta	N	6	28.55	2435.58	365.33	2800.92	1400.46	5135.03	5.13
31	*Moringa oleifera*	Senjana	N	6	38.35	6335.47	950.32	7285.79	3642.89	13357.28	13.57
32	*Pongamia pinnata*	Kalinga	N	6	27.33	2367.12	355.06	2722.19	1361.09	4990.68	4.99
33	*Tecoma stans*	Piliya	E	6	22.37	1218.6	182.79	1401.39	700.69	2569.22	2.569
34	*Elaeocarpus ganitrus*	Rudraksh	N	6	17.08	591.26	88.68	679.95	339.97	1246.58	1.24
35	*Artocarpus heterophyllus*	Kathal	N	5	37.57	4086.34	612.95	4699.29	2349.64	8615.36	8.61
36	*Nyctanthes arbor-tristis*	Parijat	N	5	13.03	226.07	33.91	259.98	129.94	476.64	0.476
37	*Chukrasia tabularis*	Chikrasi	N	4	44.004	4410.98	661.64	5072.63	2356..31	9299.82	9.29
38	*Aegle marmelos*	Bel	N	4	43.09	4004.55	600.68	4605.23	2302.61	8442.92	8.44
39	*Litchi chinensis*	Litchi	E	4	39.13	3436.45	515.46	3951.92	1975.96	7245.2	7.24
40	*Tabernaemontana divaricate*	Chandani	N	4	21.17	651.77	97.76	749.54	374.77	1374.16	1.37
41	*Bauhinia variegata*	Kachnar	N	4	18.42	517.16	77.57	594.73	297.36	1090.35	1.09

Table 1. Continued.

Sl. No.	Scientific name	Common name	Native /exotic species	Total no. of trees	Average diameter (cm)	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 eq	CO_2 eq (tons)
42	*Kigelia africana*	Balam khera	E	3	84.59	13208.99	1981.34	15190.34	7595.17	27848	27.84
43	*Nerium oleander*	Kaner	N	3	30.91	1937.87	290.68	2228.55	1114.28	4085.69	4.08
44	*Terminalia chebula*	Harad	N	3	35.42	1781.06	267.16	2048.23	1024.11	3755.08	3.755
45	*Swietenia mahagoni*	Big leaf mahagony	E	2	146.49	26468.2	3970.22	30438.42	15219.21	55803.77	55.8
46	*Holoptelea integrifolia*	Papri	N	2	133.75	21501.22	3225.18	24726.4	12363.2	45331.73	45.33
47	*Ficus virens*	Pakhan	N	2	64.02	6083.72	912.55	6996.28	3498.14	12826.52	12.82
48	*Pithocellum dube*	Jangal jalebi	E	2	61.3	4073.55	611.03	4684.59	2342.29	8588.41	8.58
49	*Ficus benghalensis*	Pukar	E	2	60.6	3934.31	590.14	4524.46	2262.33	8294.55	8.29
50	*Mitragyna parviflolia*	Gauri	N	2	32.64	954.008	143.101	1097.11	548.55	2011.36	2.011
51	*Plumeria alba*		E	2	29.14	723.43	108.52	831.95	415.97	1525.24	1.52
52	*Annona squamosa*	Sitaphal	E	2	25.47	727.12	109.06	836.19	418.09	1533.02	1.53
53	*Gmelina arborea*	Gamhar	N	1	149.68*	13589.33	2038.39	15627.73	7813.63	28650.83	28.65
54	*Bischofia javanica*	Bhilliar	N	1	121.01*	8708.18	1306.23	10014.4	5007.21	18360	18.36

Table 1. Continued.

Sl. No.	Scientific name	Common name	Native /exotic species	Total no. of trees	Average diameter (cm)	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 eq	CO_2 eq (tons)
55	*Schleichera oleosa*	Kusum	N	1	102.55*	6136.22	920.43	7056.65	3528.83	12397	12.94
56	*Barringtonia acutangula*	Hijjal	N	1	73.24*	2978.77	446.81	3425.59	1712.8	6280.3	6.28
57	*Mallotus phillippensis*	Kamala tree	N	1	55.73*	1631.48	244.72	1876.2	938.102	3439.7	3.44
58	*Magnolia grandiflora*	Him-champa	E	1	50.95*	1334.2	200.131	1534.34	767.16	2813	2.81
59	*Bauhinia purpurea*	Kaniar	N	1	46.17*	1067.006	160.05	1227.06	613.52	2249.6	2.24
60	*Ficus carica*	Anjeer	N	1	44.58*	984.62	147.69	1132.31	566.15	2075.9	2.07
61	*Dalbergia sisoo*	Shisham	N	1	35.03*	560.48	84.07	644.55	322.27	1181.7	1.18
62	*Putranjiva roxburghii*	Putijia	N	1	30.24*	393.52	59.02	452.55	226.27	829.68	0.83
63	*Saraca ashoca*	Sita Ashok	N	1	28.662*	344.55	51.68	396.23	198.11	726.44	0.72
64	*Litsea monopteala*	Meda	N	1	27.7*	316.77	47.51	364.29	182.14	667.87	0.66
65	*Butea monosperma*	Dhak	N	1	27.07*	316.77	47.51	364.29	182.14	667.87	0.66
66	*Ficus hispida*	Gobala	N	1	8.11*	12.38	1.85	14.24	7.12	26.11	0.02
67	*Albizia lebbeck*	Kala siris	N	1	23.88*	217.69	32.65	250.34	125.17	458.97	0.45

Table 1. Continued.

Sl. No.	Scientific name	Common name	Native /exotic species	Total no. of trees	Average diameter (cm)	AGB (kg)	BGB (kg)	TB (kg)	Carbon (kg)	CO_2 eq	CO_2 eq (tons)
68	*Leucaena leucocephala*	Safed babul	E	1	17.51*	95.32	14.29	109.62	54.81	200.97	0.20
69	*Ficus elastica*	Rubber tree	N	1	5.07*	10.5	1.57	12.08	6.04	22.15	0.022
70	*Eriobotrya japonica*	Lokat	E	1	14.33*	54.18	8.12	62.31	31.15	114.24	0.11
71	*Diospyros malabarica*	Gaab	N	1	12.73*	38.62	5.79	44.42	22.21	81.44	0.08
72	*Syzygium samarangese*	Jamrul	N	1	9.55*	17.54	2.63	20.17	10.08	36.98	0.03
		Total		1264		1653919	167189.5	1821108.5	790743.9	287475.1	3332.32

*Not the average value, but the diameter of single trees.

represented by 11 species), followed by Myrtaceae (5 species). The majority of the species were native (72.2%), while exotic species accounted for (22.8%) of the total. In total, 1264 individual trees were enumerated during the survey. Among these, *Mangifera indica* (231 individuals), *Monoon longifolium* (203 individuals), and *Tectona grandis* (101 individuals) were the most abundant species. The maximum diameter at breast height (DBH) was recorded in *Bombax ceiba* (248.4 cm), followed by *Ficus religiosa* (205 cm) and another *B. ceiba* individual (202.2 cm). In comparison with other University Campuses, such as Amity University (45 species), Guru Gobind Singh Indraprastha University (40 species), and DSB Campus, Kumaon University (55 species), the present study recorded a higher tree species diversity (Sharma *et al.* 2020, Mr *et al.* 2021, Bargali *et al*. 2025). This comparatively greater diversity can be attributed to the long-standing plantation history, habitat heterogeneity, and sustained conservation initiatives within the Gurukula Kangri University Campus. Being one of the Oldest Universities in India, the institution has continuously maintained and expanded its green spaces, which now serve as a refuge for native flora and play a vital role in urban biodiversity conservation.

Estimation of total biomass & carbon sequestration from the University

The above-ground and below-ground biomass of all campus trees were estimated at 1653919 kg and 167189.5 kg, respectively, resulting in a total biomass of 1821108.5 kg. The total carbon content of the campus trees was calculated as 790743.85 kg. The

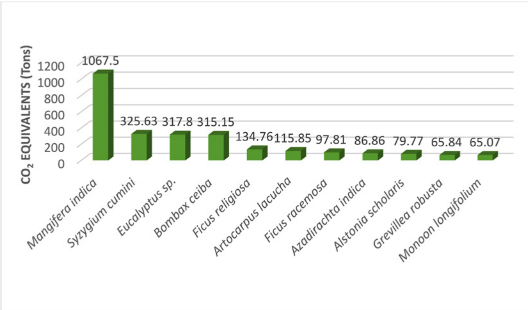

Fig. 2. Annual CO_2 sequestered by different tree species in the campus.

annual carbon sequestration potential of all trees was estimated at 3332.32 tons, with an average carbon sequestration of 2.63 tons per individual tree. Species with higher carbon sequestration equivalents are *Mangifera indica* (1067.5 tons), *Syzygium cumini* (325.63 tons), *Eucalyptus* sp. (317.8 tons), *Bombax ceiba* (315.15 tons), *Ficus religiosa* (134.76 tons), *Artocarpus lacucha* (115.85 tons), *Ficus racemosa* (97.81 tons), *Azadirachta indica* (86.86 tons), *Alstonia scholaris* (79.77 tons), *Grevillea robusta* (65.84 tons), *Monoon longifolium* (65.07 tons) as shown in (Fig. 2). Species with lower carbon sequestration equivalents are *Litsea monopteala* (0.67 tons), *Butea monosperma* (0.66 tons), *Nyctanthes arbor-tristis* (0.47 tons), *Albizia lebbeck* (0.45 tons), *Leucaena leucocephala* (0.2 tons), *Eriobotrya japonica* (0.11 tons), *Diospyros malabarica* (0.08 tons), *Syzygium samarangese* (0.03 tons), *Ficus elastica* (0.022 tons), *Ficus hispida* (0.02 tons). When compared with previous studies, the total carbon sequestration potential of trees in the present study was considerably higher than that reported by Sharma *et al.* (2020) at Amity University, Noida (139.9 tons) and by Mr. *et al.* (2021) at Guru Gobind Singh Indraprastha University, Delhi (124.14 tons). The relatively higher carbon sequestration observed in the present study may be attributed to the larger tree size, species composition, and prevalence of mature native trees within the Gurukula Kangri University Campus. The capacity for sequestering and storing carbon is influenced by factors like as species type, age, growth pattern, rainfall, and above all geographical conditions. Therefore, comparing the results of different studies remains a considerable challenge (Aguaron and McPherson 2012).

CONCLUSION

The present study demonstrates that urban trees within the Campus of Gurukula Kangri University, Haridwar, play a significant role in carbon sequestration. A total of 72 woody tree species comprising 1,264 individuals were documented, with a total carbon sequestration potential of 3,332.32 tons annually. The majority of tree species were native (72.2%), highlighting the importance of preserving indigenous biodiversity alongside exotic species (27.8%). These findings emphasize that urban green spaces not only enhance the aesthetic and ecological value of cities but also act as effective local carbon sinks, contributing to climate change mitigation. To further strengthen this role, it is recommended that urban areas increase green cover through the development of parks, strategic tree plantations and mandatory landscaping around buildings, which can serve as long-term reservoirs for atmospheric CO_2.

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