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Ecological Dynamics of Water Hyacinth in Coimbatore Lakes: Implications for Biomass, Carbon Stock, and Nutrient Management

L. Arul Pragasan [a*] and M. Vijayakumar [a,b]

[a] *Department of Environmental Sciences, Bharathiar University, Coimbatore – 641 046, Tamil Nadu, India.*
[b] *Lakshmi Card Clothing Manufacturing Company Pvt. Ltd., Coimbatore – 641 037, Tamil Nadu, India.*

Authors' contributions

This work was carried out in collaboration between both authors. Author LAP contributed by conceptualization, statistical analysis, supervision and writing of the manuscript. Author MV contributed by sample collection, laboratory analysis and data collection. Both authors read and approved the final manuscript.

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ABSTRACT

In aquatic ecosystems, water hyacinth (*Eichhornia crassipes*) often proliferates, impacting water quality and ecological balance. This study investigates the density, biomass, carbon stock, and nutrient concentrations of *E. crassipes* across five significant lakes in Coimbatore: Krishnampathy, Kurichi, Ukkadam, Singanallur, and Sulur. Field surveys, laboratory analyses and statistical methods were adopted in this study. The highest density of *E. crassipes* was observed in Krishnampathy Lake (59±2.5, no./m^2). The biomass values (kg/m^2) ranged from 1.00 to 7.33 for leaf, 3.23 to 8.03 for stalk, and from 1.47 to 10.80 for root samples. The carbon stock values (kg/m^2)

**Corresponding author: E-mail: arulpragasan@buc.edu.in;*

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ranged from 0.51 to 3.74 for leaf, 1.49 to 3.73 for stalk, and from 0.68 to 4.19 for root samples, revealing the species potential role in reducing atmospheric carbon in mitigation of climate change. We have studied the macro and micro-nutrient concentrations present in *E. crassipes*, and also we checked the relationship between chlorophyll content and nutrient concentration with the carbon stock of different plant parts of *E. crassipes*. This study contributes to a better understanding of the ecological dynamics of water hyacinth in inland water bodies and its potential implications for carbon cycling and nutrient dynamics.

Keywords: Water hyacinth; lakes; aquatic ecosystem; ecosystem management; India.

1. INTRODUCTION

Climate change and invasive species are two of the most global environmental issues [1,2]. Aquatic systems are disturbed by climate change through increasing water temperature, shifts in stream flow patterns, and intensification of storm events [3]. And, these in turn affects the distribution of species and the productivity of aquatic ecosystems [4]. Further, the anthropogenic activities such as improper waste disposal and aquarium releases have significantly accelerated the spreading of aquatic invasive species [4]. The extensive invasion of non-native species and their impacts in aquatic ecosystems are repoted worldwide [1,2,3,4,5,6,7].

One of such invasive species is the water hyacinth, *Eichhornia crassipes* (Mart.) Solms. The plant species is originated from the Amazon basin [8]. The species was first documented in 1823 by the German naturalist C. von Martius during his study of the flora of Brazil. He initially named it *Pontederia crassipes*. Sixty years later, Solms reclassified it under the Eichhornia genus, as described by Kuntz in 1829. Currently, *E. crassipes* is distributed across the tropics and subtropics, spanning between 39°N and 39°S latitudes. Human activities have been the main reason for the species' spread worldwide, notably its introduction to Africa, Asia, Australia, and North America [9]. *E. crassipes* is listed in the 100 most hazardous invasive species by the IUCN. Its rapid growth rate, successful competition with other aquatic plants, and its effortless propagation are the main reason for its global distribution [9].

Water hyacinth is recognized as one of the fastest-growing aquatic weeds globally and is considered one of the most problematic aquatic plants, with adverse effects on various aspects, including the environment and public health [10]. The water surface across a wide range of habitats are affected by the plants' biomass that frequently disrupts the utilization and management of water resources. The spread of *E. crassipes* largely affects the freshwater plant and animal population. Further, it affects the physico-chemical properties of water that includes decreases in temperature, pH, biological oxygen demand and nutrient levels [11,12,13].

Besides being an invasive species, water hyacinth has global attention for its potential in biochar production, biomethane, biohydrogen, biogas generation, and its utilization in wastewater treatment. Development of proper technology can tap the potential of *E. crassipes* in power generation. The invasive plant can serve various purposes including soil amendment, pollution abatement, carbon stock, and CO_2 capture, among others [14]. Among the greenhouse gases, the concentration of CO_2 in the atmosphere is steadily increasing, inviting immediate attention and action [15].

Ecosystems play a crucial role in exchanging carbon with the atmosphere, thus influencing Earth's climate [16]. Carbon fixed during the process of photosynthesis is stored in the biosphere over a range of timescales, from days to millennia, which are pertinent for influencing the concentration of greenhouse gases in the atmosphere [17,18]. Although there is hand full of research papers available on carbon stock potential of plants, widely researchers have neglected to study the carbon stock potential of the aquatic plants, particularly the water hyacinth.

To fill the knowledge gap, in this study we aimed to understand the ecological implications and the potentials of water hyacinth for proper management of the invasive species and the aquatic ecosystems. The main objectives are 1) to assess the density, biomass and carbon stock of water hyacinth (*E. crassipes*) in five major lakes located in Coimbatore; 2) to determine the macro and micro-nutrient concentrations present in *E. crassipes*; and 3) to explore the relationship between chlorophyll content and nutrient concentration with the carbon stock of different plant parts of *E. crassipes*.

2. MATERIALS AND METHODS

2.1 Study Area

Coimbatore, frequently hailed as the "Manchester of South India", is the second-largest city in Tamil Nadu, India. The present study was carried out in five major lakes of Coimbatore, namely Krishnampathy lake, Kurichi lake, Ukkadam lake, Singanallur lake, and Sulur lake (Fig. 1). During the period from 1991 to 2021, the study area received an average annual rainfall of 952 mm, and the average monthly temperature was 25°C [19].

2.2 Density

The density of *E. crassipes* was determined through field surveys conducted in five lakes. In each lake, three quadrats measuring 1 m × 1 m were established using nylon rope, a general method used in ecological studies [20]. Within these quadrats, all individual plants of *E. crassipes* were counted. We have calculated the density of the study plant as the number of plants per square meter (no./m^2).

2.3 Biomass

The biomass of *E. crassipes* was assessed using the quadrat method. In each quadrat, we collected all *E. crassipes* plants and weighed on-site to obtain their fresh weight. Then, we transported the plant samples to the laboratory for further analysis, including determination of moisture content, dry biomass, carbon stock, and the concentration of elements, both macro and micro-nutrients. We have presented the biomass values in kilogram per square meter (kg/m^2).

2.4 Moisture Content

We analyzed the moisture content (%) of various plant parts, including leaves, stalks, and roots, in the laboratory using the following formula,

$$MC\ (\%) = \left(\frac{Ww - Wd}{Ww}\right) \times 1$$

Where,

MC (%) = moisture content (%) of plant part
Ww = wet weight of the sample
Wd = weight of the sample after drying (at 105±5 ºC for 24 hours, in a hot air oven)

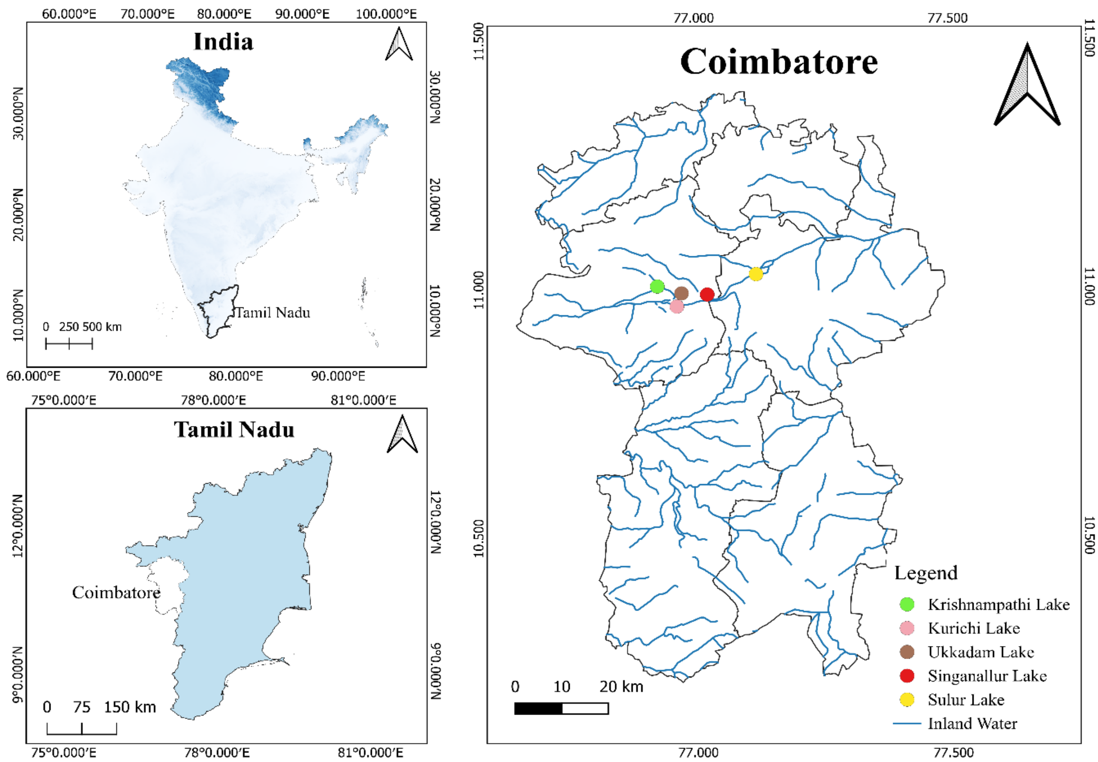

Fig. 1. Location map of the five lakes in Coimbatore District of Tamil Nadu, India

2.5 Chlorophyll Content

The leaf chlorophyll content of *E. crassipes* was measured using a Chlorophyll meter (SPAD-502 Plus, Konica Minolta Sensing, Inc., Japan). The SPAD-502 Plus measures the absorbance of the leaf in the red and near-infrared regions. Using these absorbance values, the meter calculates a numerical SPAD value that is directly proportional to the amount of chlorophyll present in the leaf. We have taken a total of fifteen chlorophyll readings at each site, totaling to seventy-five readings. We have presented the Chlorophyll content in SPAD value.

2.6 Carbon Stock

We dried the leaf, stalk, and root samples using a hot air oven for 24 hours at 105°C to obtain their dried weights. Then, one gram of the oven-dried ground samples from each plant part was individually placed in pre-weighed crucibles. And, we placed these crucibles in a furnace at 550 ± 5°C for a duration of 2 hours. We allowed the crucibles to slowly cool inside the furnace. After cooling, we weighed the crucibles containing the ash for determination of the carbon content (%) in plant parts using the following equations [21]:

$$C\ (\%) = (100 - Ash\ \%) \times 0.58$$

Where *C* (%) is percent of carbon content in plant part

$$Ash\ (\%) = \left(\frac{W3 - W1}{W2 - W1}\right) \times 100$$

Where,

W1 is the weight of Crucible
W2 the weight of oven dried grind sample + Crucible
W3 is the weight of ash + Crucible

We have calculated the carbon stock (kg/m^2) of all the plant parts, leaf, stalk and root by adopting the carbon content (%) determined for each parts and their plant biomass value obtained (mentioned above in section 2.3). The equation is provided below:

$$CS = PB \times C\ \%$$

Where,

CS is the carbon stock of plant part in kg/m^2
PB is the biomass of plant part in kg/m^2
C % is the percent of carbon content in plant part

2.7 Nutrient Concentration of *E. crassipes*

We determined the nutrient concentration in all the plant parts, leaf, Stalk and root of *E. crassipes*. The macro-nutrients include, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), and the micro-nutrients include, iron (Fe), molybdenum (Mo), copper (Cu), manganese (Mn), sodium (Na), zinc (Zn), nickel (Ni), and aluminum (Al). Nitrogen was determined using a Nitrite meter (B-74X, Horiba Scientific Ltd., Japan), while phosphorus was estimated following standard procedures outlined by American Public Health Association [22]. Calcium was determined by Calcium meter (B-751, Horiba Scientific Ltd.,Japan. The remaining elements (K, Mg, Fe, Mo, Cu, Mn, Na, Zn, Ni, and Al) were analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS, NeX Ion 300 X, Perkin Elmer, USA). The nutrients determined using ICP-MS involved a Tri-acid digestion procedure: 10 ml of tri-acid (composed of H_2SO_4, HNO_3, and $HClO_4$ in a 9:2:1 ratio) was added to 200 mg of plant sample, and the mixture was heated on a hot plate at 80°C until complete digestion of the samples. Following digestion, 100 ml of distilled water was added to the digested sample, which was then stored in a glass bottle for subsequent mineral analysis using ICP-MS.

2.8 Statistical Analysis

One-way analysis of variance (ANOVA) was performed to check for significant variations in density, moisture content, biomass, carbon stock, and nutrient concentration among the five study sites, and among the three plant parts, using SPSS software. Also, ANOVA was used to check the variation in chlorophyll content among the study sites. Pearson's Correlation analysis was used to check the relationship between leaf carbon stock and chlorophyll content, as well as the relationship between carbon stock and nutrients across different plant parts of *E. crassipes*.

3. RESULTS

3.1 Density

Among the five study sites, the density of *E. crassipes* was observed high in Krishnampathy lake (59±2.5 no./m^2), followed by Ukkadam lake, Sulur lake, Kurichi lake, and Singanallur lake (Table 1). One-way ANOVA revealed that there was no significant variation in the density of

E. crassipes among the five sites ($F_{(4,10)} = 2.071$, $p > 0.05$).

Table 1. Density of *E. crassipes* for the selected five study sites

Sites	Density (no./m^2 ± S.D.)
Krishnampathi lake	59 ± 2.5
Kurichi lake	32 ± 9.0
Ukkadam lake	35 ± 19.5
Singanallur lake	29 ± 4.9
Sulur lake	35 ± 23.8

3.2 Moisture Content

The moisture content (%) of *E. crassipes* among the five study sites varied from 60.55 ± 6.38 to 88.97 ± 0.90 for leaf; from 89.10 ± 0.13 to 95.13 ± 0.98 for stalk; from 80.30 ± 2.33 to 89.17 ± 1.61 for root (Table 2). One-way ANOVA revealed a significant variation in moisture content among the five lakes for leaf ($F_{(4,10)} = 22.936$, $p < 0.001$) and stalk ($F_{(4,10)} = 3.577$, $p < 0.05$) samples, but not for root samples ($F_{(4,10)} = 1.872$, $p > 0.05$). Among the different plant parts, statistically (one-way ANOVA) significant variation in moisture content was observed for Krishnampathy lake ($F_{(2,6)} = 56.570$, $p < 0.001$), Kurichi lake ($F_{(2,6)} = 35.790$, $p < 0.001$), and Singanallur lake ($F_{(2,6)} = 16.417$, $p < 0.01$), but not for Ukkadam lake ($F_{(2,6)} = 4.529$, $p > 0.05$) and Sulur lake ($F_{(2,6)} = 1.208$, $p > 0.05$).

3.3 Chlorophyll Content

The leaf chlorophyll content (SPAD value) of *E. crassipes* among the five study sites varied from 37.96 ± 12.86 to 48.29 ± 5.73 (Table 3). The chlorophyll content ranged from 15.3 to 63.7 among the total 75 samples collected from these sites. One-way ANOVA revealed a significant variation in leaf chlorophyll content among the five lakes ($F_{(4,70)} = 5.071$, $p > 0.05$).

3.4 Biomass

The biomass (kg/m^2) of different plant parts (leaf, stalk, and root) of *E. crassipes* across the five study sites ranged from 1.00 to 7.33 for leaf, 3.23 to 8.03 for stalk, and from 1.47 to 10.80 for root samples (Table 4). One-way ANOVA revealed that there was no significant variation in biomass values among the five lakes for leaf ($F_{(4,10)} = 0.842$, $p > 0.05$), stalk ($F_{(4,10)} = 0.420$, $p > 0.05$), as well as root samples ($F_{(4,10)} = 1.872$, $p > 0.05$). Also, no significant variation in biomass values was observed among different plant parts for Krishnampathy lake ($F_{(2,6)} = 1.809$, $p > 0.05$), Kurichi lake ($F_{(2,6)} = 0.713$, $p > 0.05$), Ukkadam lake ($F_{(2,6)} = 0.078$, $p > 0.05$), Singanallur lake ($F_{(2,6)} = 4.030$, $p > 0.05$), and Sulur lake ($F_{(2,6)} = 1.473$, $p > 0.05$).

3.5 Carbon Stock

The carbon stock (kg/m^2) of different plant parts (leaf, stalk, and root) of *E. crassipes* ranged from 0.51 to 3.74 for leaf, 1.49 to 3.73 for stalk, and from 0.68 to 4.19 for root samples (Fig. 2). One-way ANOVA revealed that there was no significant variation in carbon stock values among the five lakes for leaf ($F_{(4,10)} = 0.854$, $p > 0.05$), stalk ($F_{(4,10)} = 0.414$, $p > 0.05$), as well as root samples ($F_{(4,10)} = 1.002$, $p > 0.05$). Also, no significant variation in carbon stock values was observed among different plant parts for Krishnampathy lake ($F_{(2,6)} = 1.749$, $p > 0.05$), Kurichi lake ($F_{(2,6)} = 0.130$, $p > 0.05$), Ukkadam lake ($F_{(2,6)} = 0.008$, $p > 0.05$), Singanallur lake ($F_{(2,6)} = 3.633$, $p > 0.05$), and Sulur lake ($F_{(2,6)} = 1.472$, $p > 0.05$).

3.6 Nutrient Concentration of *E. crassipes*

The nutrient concentration determined for the different plant parts, leaf, Stalk and root of *E. crassipes* revealed that potassium (K) recorded the maximum concentration 8886.46 ppm (at Sulur lake) for leaf, 9570.22 ppm (at Singanallur lake) for stalk, and 8375.14 ppm (at Kurichi lake) for root samples, followed by magnesium (Mg) (Table 5). One-way ANOVA revealed that there was no significant variation in nutrient concentration (for all macro and micro-nutrients) among the five sites for leaf samples, except for phosphorus (P) ($F_{(4,10)} = 10.612$, $p < 0.001$); for stalk samples, except for magnesium (Mg) ($F_{(4,10)} = 3.661$, $p < 0.05$); and for all the root samples ($p > 0.05$). Also, no significant variation was observed in nutrient concentration among different plant parts for Krishnampathy lake, except for magnesium (Mg) ($F_{(2,6)} = 17.947$, $p < 0.01$) and sodium (Na) ($F_{(2,6)} = 11.859$, $p < 0.001$); for Kurichi lake, except for phosphorus (P) ($F_{(2,6)} = 12.780$, $p < 0.01$); for Singanallur lake, except for potassium (K) ($F_{(2,6)} = 10.100$, $p < 0.05$), copper (Cu) ($F_{(2,6)} = 13.622$, $p < 0.01$), and sodium (Na) ($F_{(2,6)} = 13.082$, $p < 0.01$); and for Sulur lake, except for sodium (Na) ($F_{(2,6)} = 22.626$, $p < 0.01$). While, for Ukkadam lake, one-way ANOVA revealed significant variation ($p > 0.05$) in nutrient concentration among different plant parts for all the macro and micro-nutrients.

Table 2. Moisture content (%) of *E. crassipes* by different plant parts

Sites	Leaf (Mean ± S.D.)	Stalk (Mean ± S.D.)	Root (Mean ± S.D.)
Krishnampathi lake	60.55 ± 6.38	89.10 ± 0.13	89.17 ± 1.61
Kurichi lake	88.97 ± 0.90	95.13 ± 0.98	88.22 ± 1.36
Ukkadam lake	88.06 ± 1.73	93.67 ± 3.78	88.49 ± 1.44
Singanallur lake	80.44 ± 2.23	89.50 ± 2.20	80.30 ± 2.33
Sulur lake	80.00 ± 6.00	89.25 ± 3.75	81.83 ± 11.35

Table 3. Leaf chlorophyll content (SPAD value) of *E. crassipes* across the five study sites

Sites	Chlorophyll content (Mean ± S.D.)	Range	
		Minimum	Maximum
Krishnampathy	48.29 ± 5.73	39.5	63.7
Kurichi	41.63 ± 6.20	27.2	51.5
Ukkadam	48.39 ± 7.09	31.2	57.1
Singanallur	37.96 ± 12.86	15.3	54.0
Sulur	49.17 ± 9.21	20.0	59.2

Table 4. Biomass (kg/m^2) of *E. crassipes* by different plant parts

Sites	Leaf (Mean ± S.D.)	Stalk (Mean ± S.D.)	Root (Mean ± S.D.)
Krishnampathi lake	1.56 ± 0.83	3.88 ± 1.90	2.58 ± 1.56
Kurichi lake	4.62 ± 3.28	5.59 ± 4.46	8.20 ± 3.56
Ukkadam lake	7.33 ± 10.22	8.03 ± 9.69	10.80 ± 13.90
Singanallur lake	1.00 ± 0.78	3.23 ± 1.47	1.47 ± 0.57
Sulur lake	2.59 ± 1.53	7.26 ± 5.83	13.04 ± 8.49

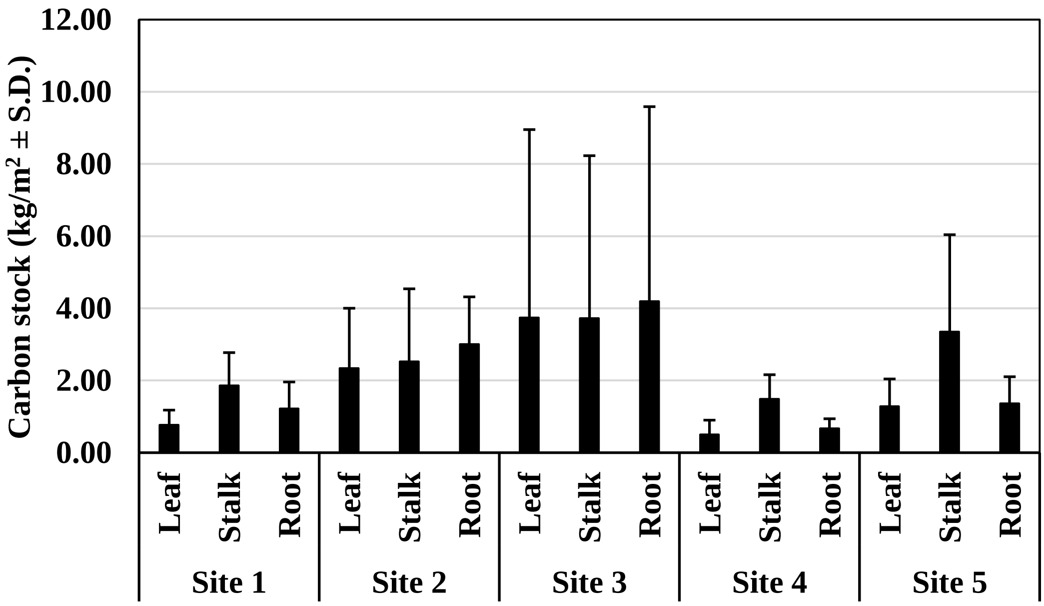

Fig. 2. Carbon stock (kg/m^2) of *E. crassipes* by different plant parts for the five study sites, Krishnampathi lake (Site 1), Kurichi lake (Site 2), Ukkadam lake (Site 3), Singanallur lake (Site 4) and Sulur lake (Site 5)

Table 5. Nutrient concentration (ppm) range (minimum (Min) and maximum (Max) values) observed for different plant parts of *E. crassipes*

Sites	Leaf		Stalk		Root	
	Min	Max	Min	Max	Min	Max
Macro-nutrients						
N						
Krishnampathi lake	66.00	78.46	183.33	184.80	47.66	90.22
Kurichi	31.53	107.06	43.26	49.13	18.55	146.66
Ukkadam	16.57	104.86	22.36	241.26	10.92	27.86
Singanallur lake	83.60	337.33	26.40	53.53	8.36	11.22
Sulur lake	9.02	27.86	17.08	29.33	9.24	9.75
P						
Krishnampathi lake	0.93	1.00	1.00	1.56	0.80	0.90
Kurichi	0.90	1.06	0.55	1.00	1.46	2.20
Ukkadam	1.33	1.96	1.00	1.56	1.13	1.96
Singanallur lake	0.76	1.00	1.16	3.20	0.83	4.17
Sulur lake	1.26	1.46	0.53	1.83	0.83	1.96
K						
Krishnampathi lake	3588.80	8726.72	1092.03	4323.95	1594.65	7664.89
Kurichi	4555.94	7057.42	5258.93	6585.75	5238.15	8375.14
Ukkadam	2759.85	6549.88	2634.28	7590.54	1850.12	6104.87
Singanallur lake	4515.28	7326.57	8222.62	9570.22	2465.70	5815.02
Sulur lake	4184.65	8886.46	733.89	8948.34	3185.77	5008.19
Ca						
Krishnampathi lake	10.00	14.00	10.00	32.00	7.00	21.33
Kurichi	5.30	18.66	18.00	44.00	68.33	283.33
Ukkadam	3.60	8.33	5.30	32.00	11.66	113.66
Singanallur lake	2.00	11.00	2.00	18.33	3.00	7.00
Sulur lake	3.00	12.00	0.00	1.00	3.00	30.33
Mg						
Krishnampathi lake	966.35	1276.15	864.09	1292.53	1717.79	1792.26
Kurichi	1165.83	2058.07	1353.63	2086.61	892.39	2176.07
Ukkadam	953.55	2192.80	1331.61	2075.09	1333.84	2119.89
Singanallur lake	559.25	1108.83	1282.78	1572.93	829.55	2245.38
Sulur lake	929.31	1378.84	1579.09	2138.28	1055.57	1825.24
Micro-nutrients						
Fe						
Krishnampathi lake	0.65	0.67	0.94	20.20	1.02	1.86
Kurichi	0.73	31.99	0.40	10.23	0.45	10.73
Ukkadam	0.94	16.96	1.16	12.60	0.82	14.27
Singanallur lake	0.31	2.01	0.29	0.58	2.13	14.26
Sulur lake	0.50	2.62	0.33	1.49	1.01	2.93
Mo						
Krishnampathi lake	0.0016	0.0024	0.0026	0.0245	0.0016	0.0046
Kurichi	0.0011	0.0018	0.0005	0.0018	0.0002	0.0034
Ukkadam	0.0008	0.0829	0.0013	0.0028	0.0018	0.0056
Singanallur lake	0.0015	0.0039	0.0010	0.0051	0.0074	0.0379
Sulur lake	0.0000	0.0095	0.0015	0.0041	0.0007	0.0015
Cu						
Krishnampathi lake	0.017	0.018	0.019	0.050	0.014	0.052
Kurichi	0.002	0.077	0.000	0.027	0.000	0.031
Ukkadam	0.002	0.015	0.000	0.027	0.002	0.172
Singanallur lake	0.001	0.003	0.002	0.021	0.024	0.041
Sulur lake	0.001	0.003	0.005	0.033	0.007	0.016

Mn						
Krishnampathi lake	0.78	1.49	0.83	775.68	1.61	2.59
Kurichi	0.56	688.64	0.48	10.44	0.55	577.18
Ukkadam	0.73	7.70	0.51	3.76	0.69	15.24
Singanallur lake	0.16	0.83	0.23	0.56	2.86	366.81
Sulur lake	0.72	2.22	0.44	3.48	6.13	606.80
Na						
Krishnampathi lake	253.24	807.40	112.38	784.96	1250.46	1615.54
Kurichi	371.42	1987.21	4.52	3273.44	50.28	3249.65
Ukkadam	1040.01	4627.65	823.45	4321.01	435.46	4860.64
Singanallur lake	99.32	561.42	1561.47	1750.09	1244.49	2595.00
Sulur lake	194.32	530.18	1639.76	2259.19	626.54	1204.65
Zn						
Krishnampathi lake	0.088	0.843	0.131	0.409	0.056	1.046
Kurichi	0.066	0.490	0.053	0.468	0.043	0.266
Ukkadam	0.110	0.181	0.081	0.251	0.131	1.201
Singanallur lake	0.110	0.275	0.026	0.065	0.174	1.644
Sulur lake	0.042	0.575	0.039	0.180	0.064	0.260
Ni						
Krishnampathi lake	0.008	0.011	0.017	0.049	0.016	0.016
Kurichi	0.006	0.106	0.003	0.080	0.001	0.030
Ukkadam	0.004	0.030	0.007	0.035	0.003	0.157
Singanallur lake	0.001	0.006	0.003	0.005	0.020	0.117
Sulur lake	0.002	0.016	0.020	0.117	0.017	0.021
Al						
Krishnampathi lake	0.45	0.59	0.85	1007.61	0.51	52.67
Kurichi	0.39	977.90	0.29	602.20	0.29	708.83
Ukkadam	0.50	971.75	0.72	895.77	0.65	491.56
Singanallur lake	0.06	0.90	0.06	0.15	0.80	264.57
Sulur lake	0.22	1.05	0.13	0.57	38.99	379.93

3.7 Relationship of Carbon Stock and Chlorophyll Content

Pearson's Correlation analysis revealed that there was no significant relationship observed between the carbon stock of different plant parts and the leaf chlorophyll content of *E. crassipes* for the study sites, except for leaf (r = -0.50) and stalk (r = -0.59) samples of Singanallur lake, and stalk samples of Krishnampathy lake (Table 6).

3.8 Relationship of Carbon Stock and Nutrients

Statistically (Pearson's Correlation analysis), no significant relationship was observed between carbon stock and nutrient concentration for different plant parts of *E. crassipes*, except for the macro-nutrients N and stalk (r = 0.73), and Ca and root (r = -0.69) (Table 7).

Table 6. Pearson's Correlation analysis between carbon stock and chlorophyll content of *E. crassipes*

Sites	Leaf carbon stock vs Chlorophyll content (r value)	Stalk carbon stock vs Chlorophyll content (r value)	Root carbon stock vs Chlorophyll content (r value)
Krishnampathi lake	-0.31	0.61	0.37
Kurchi lake	-0.03	0.30	-0.09
Ukkadam lake	-0.42	0.34	-0.18
Singanallur lake	-0.50	-0.23	-0.59
Sulur lake	-0.03	-0.12	0.04

Table 7. Pearson's Correlation analysis between carbon stock and nutrient concentration of *E. crassipes*

Elements	Leaf carbon stock vs nutrient concentration (r value)	Stalk carbon stock vs nutrient concentration (r value)	Root carbon stock vs nutrient concentration (r value)
Macro-nutrients			
N	0.27	0.73	-0.17
P	-0.02	-0.03	-0.06
K	-0.62	-0.22	-0.49
Ca	-0.26	-0.19	-0.69
Mg	0.11	-0.28	0.20
Micro-nutrients			
Fe	0.30	-0.01	0.05
Mo	-0.001	0.36	0.34
Cu	0.07	0.14	0.14
Mn	0.16	0.14	-0.23
Na	0.48	-0.13	0.03
Zn	-0.32	0.30	0.28
Ni	0.16	-0.15	0.22
Al	0.47	-0.11	-0.28

4. DISCUSSION

Global climate change and the invasion of *E. crassipes* affects the aquatic ecosystems, it is of urgent need to understand the ecological dynamics of the species for aquatic ecosystem management and environmental conservation [1,2,7]. The results of this study provides valuable information on the ecology of *E. crassipes* in the Coimbatore lakes of India.

The density of *E. crassipes* was highest in Krishnampathy lake (59±2.5 no./m^2). However, no significant variation was observed across the five study sites highlights the widespread presence of this invasive species in Coimbatore lakes. This aligns with previous research [1,2,3,4,10,19] emphasizing the rapid proliferation of water hyacinth in various aquatic habitats, driven by factors such as nutrient enrichment and favorable environmental conditions.

Also, no significant variation (ANOVA, $p > 0.05$) in plant biomass was observed among the study sites for all the three plant parts, leaf, stalk and root. The carbon stock (kg/m^2) of *E. crassipes* ranged from 0.51 to 3.74 for leaf, 1.49 to 3.73 for stalk, and from 0.68 to 4.19 for root. However, no significant variation (ANOVA, $p > 0.05$) in carbon stock was observed between the study sites for all the three plant parts. The nutrient concentration of *E. crassipes* was highest in potassium (K) for leaf, stalk, and root samples, followed by magnesium (Mg). A wide range of biomass, carbon stock and nutrient concentration values, underscores the complex interactions between water hyacinth and its surrounding environment. These insights resonate with broader ecological studies elucidating the intricate ecological dynamics within aquatic ecosystems.

The plant's ability to accumulate and remove nutrients underscores its potential as a natural filtration system [23]. This nutrient removal efficiency suggests water hyacinth could be instrumental in eco-restoration efforts for wetland ecosystems. Harnessing its potential may offer sustainable solutions for mitigating eutrophication and restoring ecological balance, facilitating the rejuvenation of degraded habitats.

Pearson's Correlation analysis revealed that there was no significant relationship observed between the carbon stock of different plant parts and the leaf chlorophyll content of *E. crassipes* for the study sites, except for leaf (at Krishnampathy and Singanallur lakes) and stalk (at Krishnampathy lake) samples. Further, no significant relationship was observed between carbon stock and nutrient concentration for different plant parts of *E. crassipes*, except for the macro-nutrients N (with stalk carbon stock, $r = 0.73$), and Ca (with root carbon stock, $r = -0.69$). This reveals the nuanced relationships between carbon stock, chlorophyll content, and nutrient concentrations in water hyacinth. The overall lack of consistent patterns suggests the multifaceted nature of carbon stock processes in

E. crassipes. These results echo existing literature on the complex interaction between plant physiology, nutrient availability, and environmental conditions in shaping carbon dynamics within aquatic vegetation communities [11].

Notably, this study underscores the importance of integrating ecological research with practical management strategies for invasive species control and ecosystem restoration. Effective management of water hyacinth requires a holistic approach that considers not only its ecological impacts but also socio-economic factors, stakeholder engagement, and adaptive management frameworks. By elucidating the ecological dynamics and carbon stock potential of *E. crassipes* in Coimbatore lakes, this research contributes valuable insights to inform evidence-based decision-making and conservation practices.

Although, there are studies available on *E. crassipes* from other regions, comparing the present study with them is not possible due to their focus on different aspects. Like, Jaiswal [23] studied the water hyacinth's pivotal role in enhancing water quality and influencing nutrient dynamics in lakes. Aswathy et al. [24] proposed a technology for producing bioethanol from water hyacinth biomass. Water hyacinth has emerged as a promising biosorbent for removing heavy metals from industrial effluents [25]. In our study too we have observed presence of metal elements (Table 5) indirectly pointing the pollution status of the lakes. Earlier, it was reported that 17 physicochemical parameters exceeded WHO pollution thresholds in the Krishnampathy lake, Kurichi lake, Ukkadam lake, Singanallur lake, and Sulur lake in the Coimbatore district of Tamil Nadu, except for Sodium, Nitrate, and Sulphate. However, the concentrations of 10 heavy metal elements remained within WHO-recommended standards for drinking water in all lakes, except for Fe and Pb [19].

Gaurav et al. [14] investigated the synthesis and advancement of CO_2 adsorbents derived from water hyacinth. Their research revealed that the carbonization temperature influenced the textural characteristics, including surface area, porosity, and nitrogen functionalities. These factors, in turn, had a significant impact on the CO_2 adsorption capacity. Climate change would alter the ecological impacts of invasive species [2]. This can occur by high competitive and predatory effects on native species and the increased virulence of certain diseases [26]. Overall, the results of this study provide valuable information on density, biomass, carbon stock and nutrient dynamics of water hyacinth in the study sites of Coimbatore. We believe this work would help for the ecological implications of water hyacinth invasion in freshwater ecosystems.

5. CONCLUSION

We conclude that density of *E. crassipes* is high in Krishnampathy lake among the five major lakes within the Coimbatore district of Tamil Nadu, India. However, no significant variations were observed among the lakes. Biomass values for leaf, stalk, and root varied across the lakes, while carbon stock values exhibited a wide range as well. Nutrient concentrations, including both macro and micro-nutrients, were determined for different plant parts, with potassium showing the highest concentration across all parts. Correlation analysis revealed that there was no significant relationship observed between the carbon stock of different plant parts and the leaf chlorophyll content of *E. crassipes* for the study sites, except for Krishnampathy and Singanallur lakes. Further, no consistent correlations were found between carbon stock and nutrient concentrations across different plant parts of *E. crassipes*. This study provides valuable insights into the ecological dynamics and carbon stock potential of *E. crassipes* in the Coimbatore lakes of India, contributing to our understanding of aquatic ecosystem management and environmental health. We suggest for the integrated approaches to mitigate the impacts of invasion of water hyacinth, involving the local people for biomass harvesting of *E. crassipes* thereby proving job opportunity for them. More research and collaborative works are necessary to develop sustainable management strategies that balance ecological conservation with human needs and societal well-being.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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