Original Research Article

Water hyacinth (*Eichhornia crassipes*) in Coimbatore Lakes: Insights into Density, Biomass, Carbon stock, and Nutrient Dynamics for Environmental Conservation Strategies

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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) ranged from 50.61 to 373.85 for leaf, 148.64 to 372.89 for stalk, and from 67.58 to 419.29 for root samples, revealing the species potential role in reducing atmospheric carbon in mitigation of climate change. Also, this study examines the macro and micro-nutrient composition of the plant species and explores their relationship with carbon stock capacity. Further, it investigates the correlation between chlorophyll content and leaf carbon stock in *E. crassipes*. The findings of this study contribute 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 represent two of the most persistent challenges within the realm of global environmental transformation [1]. Climate change will impact aquatic systems through the warming of water temperatures, shifts in stream flow patterns, and intensification of storm events [2]. These alterations are anticipated to have profound implications for the distribution and timing of species, as well as the productivity of aquatic ecosystems [3]. Humans have significantly accelerated the dissemination of aquatic invasive species through deliberate stocking, aquarium releases, canal construction, and global shipping [4]. A significant number of literature comprehensively reported the extensive invasion of non-native species and their consequential impacts in aquatic systems [5,6,7].

The water hyacinth, *Eichhornia crassipes* (Mart.) Solms is an invasive plant originating from the Amazon basin [8]. Its prolific growth and propagation capacity pose significant conservation challenges, leading to substantial socioeconomic consequences [9]. While possessing considerable ornamental value in gardening due to its attractive foliage and flowers, the water hyacinth is listed among the 100 most hazardous invasive species by the IUCN [9]. The majority of challenges linked to *E. crassipes* stem from its rapid growth rate, successful competition with other aquatic plants, and its effortless propagation. These attributes result in the generation of vast amounts of biomass that blanket the water surface across a wide range of habitats, frequently disrupting the utilization and management of water resources. Among the primary issues are its interference with navigation, water flow, and recreational activities in aquatic systems, as well as the threat it poses of mechanical damage to hydroelectric systems. Additionally, it induces significant alterations in freshwater plant and animal communities and serves as a vector for the dissemination of severe diseases in tropical regions. The influence of *E. crassipes* on the physico-chemical properties of water typically includes decreases in temperature, pH, biological oxygen demand (organic load), and nutrient levels [10]. In some instances, there is a complete depletion of dissolved oxygen, resulting in the mortality of a large number of fish.

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 activity has indisputably been the primary agent driving the species' spread worldwide, as its introduction to Africa, Asia, Australia, and North America coincided with the arrival of vessels by early explorers or documented human activities throughout history [9].

Water hyacinth has garnered significant attention for its potential in biochar production, biomethane, biohydrogen, biogas generation, and its utilization in wastewater treatment. Even more targeted focus is required to develop integrated decentralized water systems and produce the most valuable and high-quality products, such as biochar, for use in power generation. They can serve various purposes including soil amendment, pollution abatement, carbon stock, and CO_2 capture, among others [11].

Among the greenhouse gases, the concentration of CO_2 in the atmosphere is steadily increasing, necessitating urgent attention and action [12]. 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 [12,13].

Ecosystems play a crucial role in exchanging carbon with the atmosphere at globally significant quantities, thus influencing Earth’s climate and potentially mitigating the warming caused by increasing concentrations of CO_2 in the atmosphere [14]. Carbon fixed during the process of photosynthesis remains 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 [15,16]. Widely researchers have neglected to study the carbon stock potential of the aquatic plants, particularly the water hyacinth.

The present study aims 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 of this study is to assess the density, biomass and carbon stock of water hyacinth (*E. crassipes*) in five prominent lakes located in Coimbatore, including Krishnampathy, Kurichi, Ukkadam, Singanallur, and Sulur lakes, alongside analyzing the macro and micro-nutrient concentrations present in the plant species. Further, the study endeavors to explore the relationship between chlorophyll content and the leaf carbon stock potential of *E. crassipes*, as well as investigate the correlation between macro and micro-nutrient levels and the plant's carbon stock potential.

2. MATERIAL 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). Over the span of 1991 to 2021, the study area received an average annual rainfall of 952 mm, and the average monthly temperature was 25°C [17].

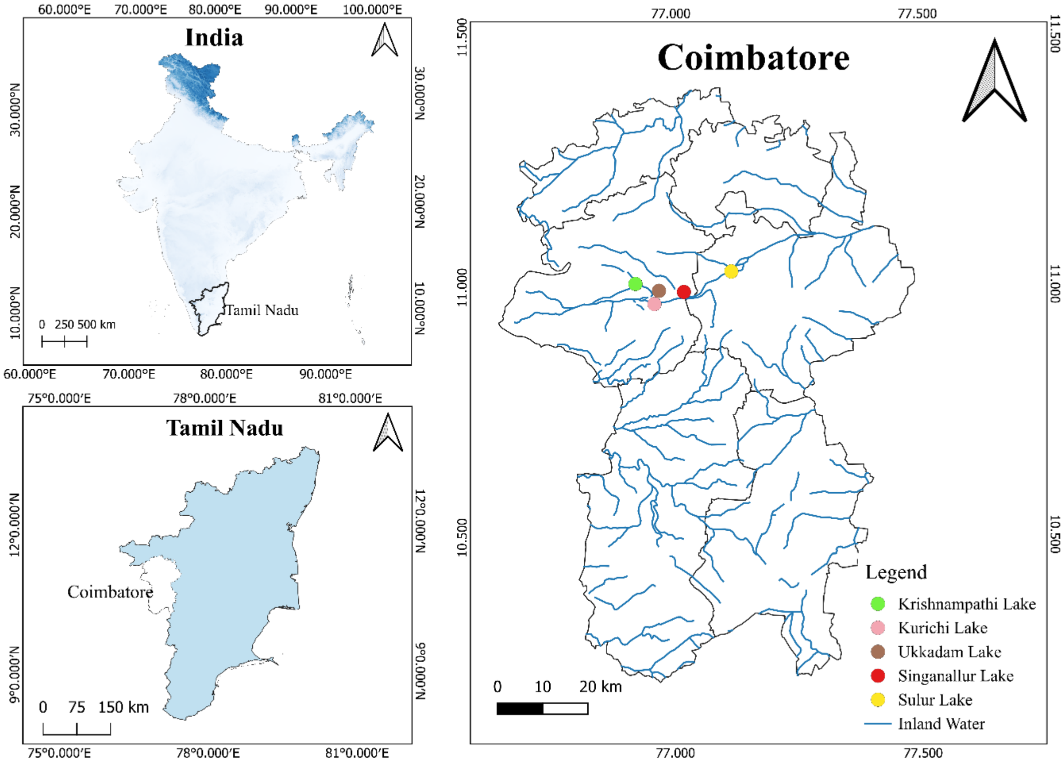

Fig. 1. Location map of the five lakes in Coimbatore district of Tamil Nadu, India

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. Within these quadrats, all individual plants of *E. crassipes* were counted. The density of the study plant was then calculated as the number of plants per square meter.

2.3 Biomass

The biomass of *E. crassipes* was assessed using the quadrat method. In each quadrat, all *E. crassipes* plants were collected and weighed on-site to obtain their fresh weight. Subsequently, plant samples were transported 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.

2.4 Moisture content

The moisture content of various plant parts, including leaves, stalks, and roots, was analyzed in the laboratory using the following formula,

MC (%)= ((Ww-Wd)/Ww) x 100
Eq.1

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

2.5 Chlorophyll content

The leaf chlorophyll content of *E. crassipes* was measured using a Chlorophyll meter. A total of fifteen chlorophyll readings were taken at each site, amounting to seventy-five readings in total.

2.6 Carbon stock

Leaf, stalk, and root samples were subjected to drying in a hot air oven for 24 hours at 105°C to obtain their dried weights. Subsequently, one gram of the oven-dried ground samples from each plant part was individually placed in pre-weighed crucibles. These crucibles were then placed in a furnace at 550±5°C for a duration of 2 hours. Afterward, the crucibles were slowly cooled within the furnace. Following cooling, the crucibles containing the ash were weighed to facilitate the calculation of the carbon stock using the following equations,

C (%) = (100 - Ash %) x 0.58 Eq.2
Where C (%) is carbon stock %
Ash (%) = (W3 – W1)/ (W2 – W1) x 100 Eq.3
Where W1 is the weight of Crucible
W2 the weight of oven dried grind sample + Crucible
W3 is the weight of ash + Crucible

2.7 Nutrient concentration of *E. crassipes*

The concentration of macro-nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), as well as micro-nutrients such as iron (Fe), molybdenum (Mo), copper (Cu), manganese (Mn), sodium (Na), zinc (Zn), nickel (Ni), and aluminum (Al), was determined for various plant parts of *E. crassipes*. Nitrogen was estimated using a Nitrite meter, while phosphorus (from PO4) was assessed through standard methods outlined in APHA 1985. Calcium levels were determined using a Calcium meter. The remaining elements (K, Mg, Fe, Mo, Cu, Mn, Na, Zn, Ni, and Al) were analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). The mineral analysis using ICP-MS involved a Tri-acid digestion procedure: 10 ml of tri-acid (composed of H2SO4, HNO3, and HClO4 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

The results are reported as mean values along with their corresponding standard deviations. To assess significant variations, one-way analysis of variance (ANOVA) was conducted using SPSS software. Further, Pearson's Correlation analysis was used to examine the relationship between leaf carbon stock and chlorophyll content, as well as the relationship between carbon stock and the various nutrients across different plant parts of *E. crassipes*.

3. RESULTS AND DISCUSSION

3.1 Density

Table 1 presents the density of *E. crassipes* across the five study sites. The highest density of *E. crassipes* was observed in Krishnampathy lake (59±2.5 no./m^2), followed by Ukkadam lake, Sulur lake, Kurichi lake, and Singanallur lake (Table 1). Statistical analysis using one-way ANOVA indicated 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

Table 2 presents the moisture content of different plant parts (leaf, stalk, and root) of *E. crassipes* across the selected five study sites. A significant variation in moisture content was observed 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 ($F_{(4,10)} = 1.872$, $p > 0.05$). Further, significant differences in moisture content were found among different plant parts 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 ($F_{(2,6)} = 1.208$, $p > 0.05$).

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

3.3 Chlorophyll content

Table 3 displays the leaf chlorophyll content of *E. crassipes* across the five study sites. The chlorophyll content ranged from 15.3 to 63.7 among the total 75 samples collected from these sites. Statistical analysis revealed a significant variation in leaf chlorophyll content among the five lakes ($F_{(4,70)} = 5.071$, $p > 0.05$).

Table 3. Leaf chlorophyll content of *E. crassipes* across the five study sites

Sites	Chlorophyll content (± S.D.)	Range
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

3.4 Biomass

Table 4 presents the biomass (kg/m^2) of different plant parts (leaf, stalk, and root) of *E. crassipes* across the five study sites. The biomass values 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. Statistical analysis indicated 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 ($F_{(2,6)} = 1.473$, $p > 0.05$).

Table 4. Biomass 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

3.5 Carbon stock

Table 5 provides the carbon stock (kg/m^2) of different plant parts (leaf, stalk, and root) of *E. crassipes* across the selected five study sites in Coimbatore. The carbon stock values ranged from 50.61 to 373.85 for leaf, 148.64 to 372.89 for stalk, and from 67.58 to 419.29 for root samples. Statistical analysis revealed 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 ($F_{(2,6)} = 1.472$, $p > 0.05$).

Table 5. Carbon stock (kg/m^2) of *E. crassipes* by different plant parts

Sites	Leaf	Stalk	Root

	(Mean ± S.D.)	(Mean ± S.D.)	(Mean ± S.D.)
Krishnampathi lake	76.90 ± 41.09	185.96 ± 91.27	122.24 ± 73.70
Kurichi lake	233.98 ± 166.28	252.62 ± 201.45	300.93 ± 130.80
Ukkadam lake	373.85 ± 521.45	372.89 ± 450.12	419.29 ± 539.56
Singanallur lake	50.61 ± 39.52	148.64 ± 67.39	67.58 ± 26.37
Sulur lake	128.49 ± 75.75	334.90 ± 269.12	136.42 ± 73.95

3.6 Nutrient concentration of *E. crassipes*

Table 6 presents the concentration (ppm) of different elements (macro-nutrients: N, P, K, Ca, and Mg; and micro-nutrients: Fe, Mo, Cu, Mn, Na, Zn, Ni, and Al) found in various plant parts of *E. crassipes* across the five study sites. Among these elements, potassium (K) exhibited the highest concentration, recorded as 5476.39 ppm for leaf, 5801.99 ppm for stalk, and 4657.42 ppm for root samples, followed by magnesium (Mg), sodium (Na), and aluminum (Al) (Fig. 2).

Statistical analysis revealed no significant variation in the concentration of elements (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 ($p > 0.05$). Similarly, no significant variation was observed in the concentration of elements 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 Ukkadam lake; 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) ($F_{(2,6)} = 13.082$, $p < 0.01$); as well as for Sulur lake, except for sodium (Na) ($F_{(2,6)} = 22.626$, $p < 0.01$).

Table 6. Concentration of macro and micro-nutrients in *E. crassipes* by different plant parts across the five study sites

Sites	Leaf (Mean ± S.D.)	Stalk (Mean ± S.D.)	Root (Mean ± S.D.)
Macro-nutrients			
N			
Krishnampathi lake	72.11 ± 6.23	184.31 ± 0.85	62.09 ± 24.36
Kurchi lake	77.73 ± 40.49	45.22 ± 3.39	64.63 ± 71.43
Ukkadam lake	56.63 ± 45.025	96.18 ± 125.65	20.50 ± 8.69
Singanallur lake	187.73 ± 132.84	41.84 ± 13.93	9.90 ± 1.44
Sulur lake	17.11 ± 9.70	23.29 ± 6.13	9.56 ± 0.28
P			
Krishnampathi lake	0.96 ± 0.04	1.22 ± 0.30	0.85 ± 0.05
Kurchi lake	0.97 ± 0.08	0.72 ± 0.25	1.77 ± 0.38
Ukkadam lake	1.60 ± 0.33	1.30 ± 0.28	1.63 ± 0.44
Singanallur lake	0.85 ± 0.13	2.14 ± 1.02	2.28 ± 1.71
Sulur lake	1.36 ± 0.10	1.19 ± 0.65	1.35 ± 0.57
K			
Krishnampathi lake	6153.10 ± 2568.97	2727.22 ± 1616.30	4615.69 ± 3035.22
Kurchi lake	5445.52 ± 1398.45	5875.02 ± 668.45	6755.26 ± 1571.02
Ukkadam lake	4126.47 ± 2104.44	5165.78 ± 2479.85	3991.35 ± 2127.51
Singanallur lake	5502.13 ± 1581.77	9040.16 ± 718.33	4066.60 ± 1679.53
Sulur lake	6154.71 ± 2441.70	6201.80 ± 4735.37	3858.22 ± 1000.66
Ca			
Krishnampathi lake	12.20 ± 2.03	21.00 ± 11.00	14.11 ± 7.17

Kurchi lake	12.32 ± 6.71	28.33 ± 13.80	143.55 ± 121.17
Ukkadam lake	6.09 ± 2.37	15.10 ± 14.70	74.33 ± 54.86
Singanallur lake	5.33 ± 4.93	7.78 ± 9.15	4.78 ± 2.04
Sulur lake	6.33 ± 4.93	0.33 ± 0.58	12.78 ± 15.23
Mg			
Krishnampathi lake	1119.06 ± 154.95	1081.12 ± 214.28	1752.50 ± 37.49
Kurchi lake	1538.28 ± 464.01	1654.66 ± 383.63	1394.35 ± 686.04
Ukkadam lake	1682.35 ± 647.84	1746.73 ± 379.26	1796.34 ± 411.03
Singanallur lake	763.08 ± 301.03	1388.87 ± 160.02	1468.70 ± 717.87
Sulur lake	1164.57 ± 225.50	1951.18 ± 322.24	1544.37 ± 424.89
Micro-nutrients			
Fe			
Krishnampathi lake	0.66 ± 0.01	10.45 ± 9.63	1.45 ± 0.42
Kurchi lake	11.57 ± 17.70	3.85 ± 5.53	4.99 ± 5.25
Ukkadam lake	7.05 ± 8.65	5.15 ± 6.46	5.33 ± 7.75
Singanallur lake	0.92 ± 0.95	0.40 ± 0.15	6.49 ± 6.75
Sulur lake	1.54 ± 1.06	0.78 ± 0.63	2.27 ± 1.09
Mo			
Krishnampathi lake	0.002 ± 0.0004	0.01 ± 0.01	0.003 ± 0.001
Kurchi lake	0.001 ± 0.0003	0.001 ± 0.001	0.002 ± 0.002
Ukkadam lake	0.03 ± 0.05	0.002 ± 0.001	0.004 ± 0.002
Singanallur lake	0.002 ± 0.001	0.003 ± 0.002	0.02 ± 0.02
Sulur lake	0.004 ± 0.005	0.003 ± 0.001	0.001 ± 0.0005
Cu			
Krishnampathi lake	0.02 ± 0.001	0.04 ± 0.02	0.03 ± 0.02
Kurchi lake	0.03 ± 0.04	0.01 ± 0.01	0.01 ± 0.02
Ukkadam lake	0.01 ± 0.01	0.01 ± 0.01	0.06 ± 0.09
Singanallur lake	0.0014 ± 0.0012	0.008 ± 0.01	0.03 ± 0.009
Sulur lake	0.002 ± 0.001	0.02 ± 0.02	0.01 ± 0.004
Mn			
Krishnampathi lake	1.11 ± 0.36	272.02 ± 436.61	2.09 ± 0.49
Kurchi lake	230.05 ± 397.15	4.06 ± 5.54	193.50 ± 332.28
Ukkadam lake	3.25 ± 3.86	1.92 ± 1.67	5.69 ± 8.28
Singanallur lake	0.39 ± 0.38	0.34 ± 0.19	124.79 ± 209.60
Sulur lake	1.24 ± 0.84	1.94 ± 1.52	264.41 ± 309.04
Na			
Krishnampathi lake	538.03 ± 277.40	343.18 ± 382.72	1433.81 ± 182.55
Kurchi lake	936.20 ± 911.05	1225.08 ± 1784.77	1175.65 ± 1798.31
Ukkadam lake	2244.40 ± 2064.00	2056.61 ± 1963.62	2252.52 ± 2316.22
Singanallur lake	274.69 ± 250.36	1658.74 ± 94.45	1899.12 ± 676.20
Sulur lake	394.10 ± 176.76	1894.26 ± 324.14	967.46 ± 302.69
Zn			
Krishnampathi lake	0.39 ± 0.40	0.27 ± 0.14	0.56 ± 0.49
Kurchi lake	0.22 ± 0.24	0.19 ± 0.24	0.17 ± 0.12
Ukkadam lake	0.15 ± 0.04	0.17 ± 0.09	0.57 ± 0.56
Singanallur lake	0.21 ± 0.09	0.04 ± 0.02	0.73 ± 0.80
Sulur lake	0.25 ± 0.28	0.09 ± 0.08	0.16 ± 0.10

Ni			
Krishnampathi lake	0.01 ± 0.001	0.03 ± 0.02	0.02 ± 0.0001
Kurchi lake	0.04 ± 0.06	0.03 ± 0.04	0.02 ± 0.01
Ukkadam lake	0.01 ± 0.01	0.02 ± 0.02	0.06 ± 0.09
Singanallur lake	0.003 ± 0.003	0.004 ± 0.001	0.06 ± 0.05
Sulur lake	0.01 ± 0.01	0.06 ± 0.05	0.02 ± 0.002
Al			
Krishnampathi lake	0.52 ± 0.07	503.60 ± 503.38	26.35 ± 26.08
Kurchi lake	395.23 ± 515.11	201.20 ± 347.28	266.36 ± 385.80
Ukkadam lake	399.43 ± 508.31	307.27 ± 509.80	171.80 ± 277.15
Singanallur lake	0.35 ± 0.48	0.09 ± 0.05	112.57 ± 136.41
Sulur lake	0.69 ± 0.42	0.30 ± 0.24	207.84 ± 170.50

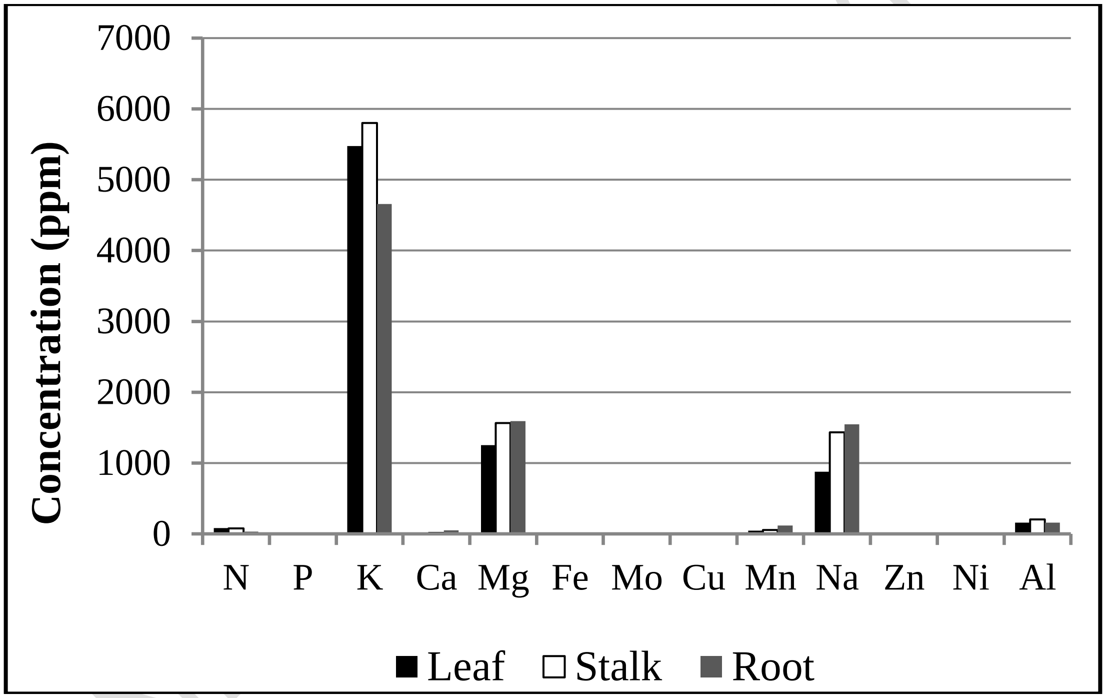

Fig. 2. Elemental concentration for different plant parts of *E. crassipes*

3.7 Relationship of leaf carbon stock and chlorophyll content

Table 7 presents the relationship between carbon stock and chlorophyll content of leaf samples of *E. crassipes* across the five study sites. No significant correlation was found 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 (r = 0.61).

Table 7. Relationship of carbon stock and chlorophyll content of leaf samples of *E. crassipes* among the five study sites

Sites	Leaf	Stalk	Root
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

3.8 Relationship of carbon stock and nutrients

Table 8 displays the relationship between carbon stock and various elements in different plant parts of *E. crassipes* across the five study sites. No significant correlation 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 8. Relationship of carbon stock and nutrients for different plant parts of *E. crassipes*

Elements	Leaf	Stalk	Root
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

The findings from the study on *E. crassipes* in the lakes of Coimbatore district, Tamil Nadu, offer significant contributions to the broader discourse on aquatic ecosystem management and environmental conservation. Several key points emerge from this comprehensive analysis, inviting deeper discussion and connection with existing literature.

Firstly, the study highlights the variability in density and biomass of *E. crassipes* across different lakes. While Krishnampathy lake exhibited the highest density, the absence of significant variations among the lakes underscores the widespread presence and potential impact of this invasive species. This aligns with previous research [8,9,10,17] emphasizing the rapid proliferation of water hyacinth in various aquatic habitats, driven by factors such as nutrient enrichment, favorable environmental conditions, and limited natural predators or competitors.

Moreover, the variation in biomass values for different plant parts, alongside the wide range of carbon stock values, underscores the complex interactions between water hyacinth and its surrounding environment. This complexity is further underscored by the diverse nutrient concentrations found in various plant parts, with potassium emerging as a dominant element. Such insights resonate with broader ecological studies elucidating the intricate nutrient dynamics within aquatic ecosystems and the role of invasive species in nutrient cycling and redistribution. The plant's ability to accumulate and remove nutrients underscores its potential as a natural filtration system [18]. This nutrient removal efficiency suggests water hyacinth could be instrumental in eco-restoration efforts for wetland ecosystems. Harnessing its capabilities may offer sustainable solutions for mitigating eutrophication and restoring ecological balance, facilitating the rejuvenation of degraded habitats.

The correlation analyses conducted in the present study reveal nuanced relationships between carbon stock, chlorophyll content, and nutrient concentrations in water hyacinth. While significant correlations were observed in certain samples, the overall lack of consistent patterns suggests the multifaceted nature of carbon stock processes in *E. crassipes*. These findings echo existing literature [10] on the complex interplay between plant physiology, nutrient availability, and environmental conditions in shaping carbon dynamics within aquatic vegetation communities.

Importantly, the 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 the studied lakes, this research contributes valuable insights to inform evidence-based decision-making and conservation practices.

While studies on *E. crassipes* from other regions exist, comparing them to the present study is not feasible due to their focus on different aspects. Like, Jaiswal's [18] study reveals water hyacinth's pivotal role in enhancing water quality and influencing nutrient dynamics in lakes. Aswathy et al. (2010) [19] proposed a technology for producing bioethanol from water hyacinth biomass.

Heavy metal ions are getting more notice due to their prevalence in industrial waste, their harmful effects on water ecosystems, and their toxicity. Water hyacinth has emerged as a promising biosorbent for removing these heavy metals from industrial effluents [20]. In our study too we have observed presence of metal elements (Table 6) 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 [17].

Gaurav et al. (2020) [11] 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. This would occur through heightened competitive and predatory effects on native species and the increased virulence of certain diseases [1].

Overall, the findings from this study enrich our understanding of the ecological implications of water hyacinth invasion in freshwater ecosystems and highlight the importance of integrated approaches to mitigate its impacts. Moving forward, further research efforts and collaborative initiatives are needed to develop sustainable management strategies that balance ecological conservation with human needs and societal well-being.

4. CONCLUSION

The study conducted a comprehensive analysis of various aspects of *E. crassipes* in five major lakes within the Coimbatore district of Tamil Nadu, India. Density assessments revealed Krishnampathy lake as having the highest density of *E. crassipes*, although 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 analyses revealed significant relationships between leaf carbon stock and chlorophyll content in certain samples, notably in Singanallur and Krishnampathy lakes. However, overall, no consistent correlations were found between carbon stock and nutrient concentrations across different plant parts of *E. crassipes*. These findings provide valuable insights into the ecological dynamics and carbon stock potential of *E. crassipes* in the studied lakes, contributing to our understanding of aquatic ecosystem management and environmental conservation efforts.

REFERENCES

1. Rahel FJ, Olden JD. Assessing the effects of climate change on aquatic invasive species. Conservation Biology. 2008;22(3):521-33.
2. Poff NL, Brinson MM, Day JW. Aquatic ecosystems and global climate change. Pew Center on Global Climate Change, Arlington, VA. 2002;44:1-36.
3. Parmesan C. Ecological and evolutionary responses to recent climate change. Annual Review of Ecology, Evolution, and Systematics. 2006;37:637-69.
4. Rahel FJ. Biogeographic barriers, connectivity and homogenization of freshwater faunas: it's a small world after all. Freshwater Biology. 2007;52(4):696-710.
5. Strayer DL. Effects of alien species on freshwater mollusks in North America. Journal of the North American Benthological Society. 1999;18(1):74-98.
6. Lodge DM, Williams S, MacIsaac HJ, Hayes KR, Leung B, Reichard S, Mack RN, Moyle PB, Smith M, Andow DA, Carlton JT. Biological invasions: recommendations for US policy and management. Ecological Applications. 2006;16(6):2035-54.
7. Stromberg JC, Lite SJ, Marler R, Paradzick C, Shafroth PB, Shorrock D, White JM, White MS. Altered stream-flow regimes and invasive plant species: the Tamarix case. Global Ecology and Biogeography. 2007;16(3):381-93.
8. Barrett SC, Forno IW. Style morph distribution in new world populations of *Eichhornia crassipes* (Mart.) Solms-Laubach (water hyacinth). Aquatic Botany. 1982;13:299-306.
9. Téllez TR, López EM, Granado GL, Pérez EA, López RM, Guzmán JM. The water hyacinth, *Eichhornia crassipes*: an invasive plant in the Guadiana River Basin (Spain). Aquatic Invasions. 2008;3(1):42-53.

10. Rai DN, Munshi JD. The influence of thick floating vegetation (Water hyacinth: *Eichhornia crassipes*) on the physico—Chemical environment of a fresh water wetland. Hydrobiologia. 1979;62:65-9.
11. Gaurav GK, Mehmood T, Cheng L, Klemeš JJ, Shrivastava DK. Water hyacinth as a biomass: A review. Journal of Cleaner Production. 2020;277:122214.
12. Vinayakumar K, Palliyarayil A, Prakash PS, Kumar NS, Sil S. A facile one pot synthesis of biocarbon derived from water hyacinth and development of pellets for CO_2 capture applications. Biomass and Bioenergy. 2022;167:106648.
13. Kateregga E, Sterner T. Indicators for an invasive species: Water hyacinths in Lake Victoria. Ecological Indicators. 2007;7(2):362-70.
14. Sierra CA, Crow SE, Heimann M, Metzler H, Schulze ED. The climate benefit of carbon sequestration. Biogeosciences. 2021;18(3):1029-48.
15. IPCC. Summary for policymakers. In: Climate change 2021: The physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2021.
16. Pragasan LA. Tree carbon stock and its relationship to key factors from a tropical hill forest of Tamil Nadu, India. Geology, Ecology, and Landscapes. 2022;6(1):32-9.
17. Pragasan LA, Gomathi T. Water Quality and Environmental Health of Lakes in Coimbatore, India: A Comprehensive Study of the Physicochemical Characteristics. Asian Journal of Environment & Ecology. 2024;23(7):11-24.
18. Jaiswal S. Growth and nutrient accumulation by *Eicchornia crassipes* (Mart.) solms in Robertsnon lake, Jabalpur, India. Ecoprint: an international Journal of Ecology. 2011;18:91-100.
19. Aswathy US, Sukumaran RK, Devi GL, Rajasree KP, Singhania RR, Pandey A. Bio-ethanol from water hyacinth biomass: an evaluation of enzymatic saccharification strategy. Bioresource Technology. 2010;101(3):925-30.
20. Zheng JC, Feng HM, Lam MH, Lam PK, Ding YW, Yu HQ. Removal of Cu (II) in aqueous media by biosorption using water hyacinth roots as a biosorbent material. Journal of hazardous materials. 2009;171(1-3):780-5.