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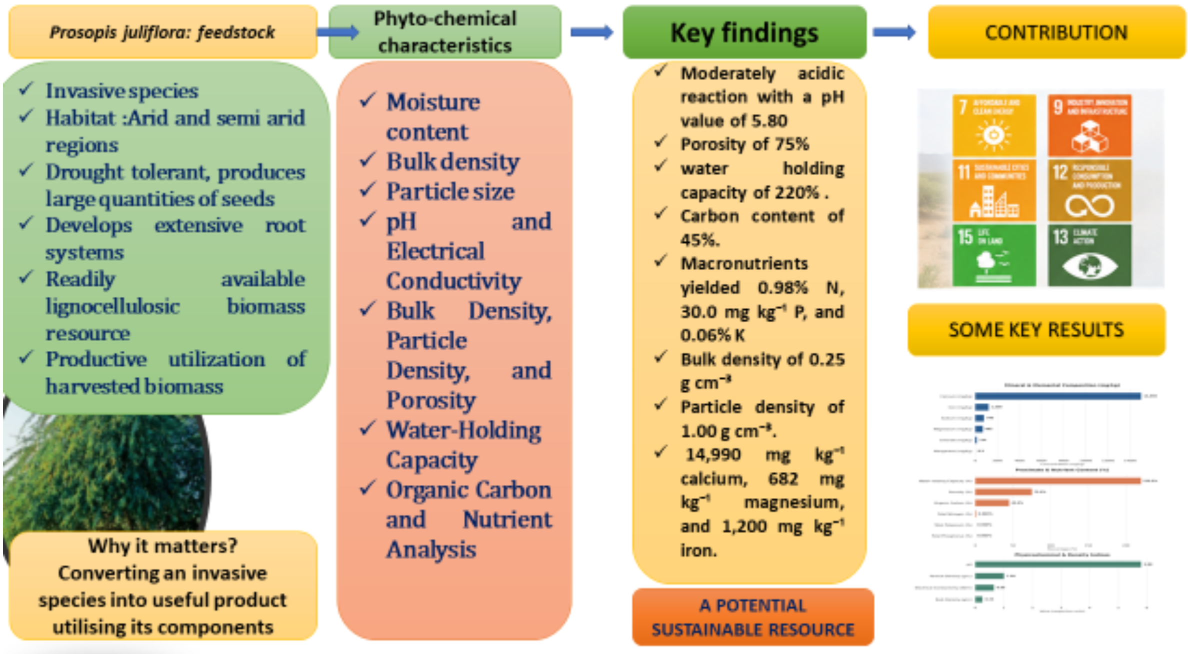
Original Research Paper

# PHYSICOCHEMICAL CHARACTERIZATION OF *PROSOPIS JULIFLORA* BIOMASS FOR SUSTAINABLE RESOURCE UTILIZATION: A CLIMATE ACTION
## INITIATIVE TOWARDS SDG 13

**Shilpa Neelam S[1], Baba Uqab[2*] and Akshi Goyal[3]**
[1,2,3]Department of Environmental Sciences, SRM University, Delhi –NCR, Sonipat, India
Corresponding Author: *uqabali@srmuniversity.ac.in
ORCID: https://orcid.org/0009-0009-8157-7947

## GRAPHICAL ABSTRACT




## ABSTRACT
Background: Prosopis juliflora is an invasive woody species that produces substantial quantities of biomass in arid and semi-arid regions. Baseline physicochemical characterization is required before specific utilization pathways are evaluated. This study characterized selected physical, chemical, and mineral properties of Prosopis juliflora biomass collected from two locations in Coimbatore District, Tamil Nadu, India.

Methods: Equal proportions of processed biomass from the two sampling locations were homogenized to prepare a composite sample. Selected physicochemical parameters were measured in triplicate as analytical replicates of the composite sample.

Results: The biomass had a pH of 5.80, electrical conductivity of 0.65 dS $m^{-1}$, bulk density of 0.25 g $cm^{-3}$, particle density of 1.00 g $cm^{-3}$, porosity of 75%, and water-holding capacity of 220%. Organic carbon was 45%, total nitrogen was 0.98%, available phosphorus was 30.0 mg $kg^{-1}$, and total potassium was 0.06%. Calcium, magnesium, sodium, chloride, iron, and manganese were recorded at 14,990, 682, 780, 144, 1,200, and 8.5 mg $kg^{-1}$, respectively. Cadmium, chromium, nickel, and lead were below the instrumental detection limits under the analytical conditions used.

Conclusion: The findings provide preliminary baseline information for the composite biomass sample prepared

***Corresponding Author:**
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from the two selected locations. They can guide future investigations of Prosopis juliflora biomass, but broader spatial sampling, independent replication, and additional structural, thermal, and application-specific performance testing are required before specific utilization pathways are established.

Methods: Standard analytical protocols were deployed to characterize the raw biomass. Biomass collected from two sampling locations was homogenized to prepare a composite sample, and all analyses were performed in triplicate. The evaluation encompassed key physical and chemical parameters, including pH, electrical conductivity (EC), bulk density, particle density, water-holding capacity (WHC), organic carbon, and primary macronutrients (nitrogen, phosphorus, potassium), alongside trace mineral constituents, to determine its overall material potential.

Results: Analytical testing revealed a moderately acidic profile (pH 5.80) and an EC of 0.65 dS $m^{-1}$. The biomass had a water-holding capacity of 220% and organic carbon content of 45%. Quantitative profiling of the macronutrients yielded 0.98% N, 30.0 mg $kg^{-1}$ P, and 0.06% K, while physical analysis showed a bulk density of 0.25 g $cm^{-3}$ and a particle density of 1.00 g $cm^{-3}$. Mineral profiling indicated 14,990 mg $kg^{-1}$ calcium, 682 mg $kg^{-1}$ magnesium, and 1,200 mg $kg^{-1}$ iron. Collectively, these physicochemical characteristics indicate that Prosopis juliflora biomass is rich in carbon and contains essential nutrients, supporting its potential for bio-based applications. The high carbon content, together with the fact that analysed heavy metals (Cd, Cr, Ni and Pb) were below detection limits, indicates potential suitability for future biochar and composite material investigations; however, further proximate, structural, and thermal analyses are required. All reported values represent the mean of triplicate analytical measurements of the homogenized composite sample.

**Conclusion:** These characteristics indicate that *Prosopis juliflora* biomass may serve as a valuable feedstock for bio-based applications. Strategically utilizing this invasive species offers a dual benefit: mitigating biological invasions to aid regional ecosystem restoration and enabling sustainable biomass management in support of global climate goals (SDG-13).

**Keywords:** Biomass utilization; Circular bioeconomy; Climate Action; *Prosopis juliflora*; Physicochemical characterization; SDG 13.

## 1. INTRODUCTION

Biological invasions have emerged as a significant environmental concern due to their influence on biodiversity, ecosystem functioning, and the availability of natural resources [1,2]. Among invasive woody species, *Prosopis juliflora* has attracted considerable attention because of its rapid spread and ability to establish under harsh environmental conditions [2,3]. The species is highly drought tolerant, produces large quantities of seeds, and develops extensive root systems, enabling it to colonize degraded and semi-arid landscapes effectively [4,5].

Initially introduced in many tropical and subtropical regions for purposes such as fuelwood production, land rehabilitation, and erosion control, *Prosopis juliflora* has subsequently expanded beyond its intended range, causing ecological and socioeconomic impacts [6,7]. Dense thickets formed by the species often suppress native vegetation, alter soil characteristics, and affect ecosystem services that support local communities [8,9]. In India, its invasion has become particularly noticeable in wastelands, riverbanks, grazing lands, and peri-urban environments, including several parts of Tamil Nadu [10,11,12].

Despite the ecological concerns associated with its spread, *Prosopis juliflora* also represents a readily available lignocellulosic biomass resource. Previous investigations have shown that its pods possess favourable characteristics for bioenergy applications [13], while fibres extracted from the bark have potential for use in biocomposite materials [14]. Productive utilization of harvested biomass may therefore provide an opportunity to address two challenges simultaneously: reducing the environmental burden caused by invasion and generating value-added products from an otherwise underutilized resource [15].

In recent years, sustainable biomass utilization has gained increasing importance within the framework of climate-responsive development strategies and the Sustainable Development Goals. However, efficient utilization of biomass requires a clear understanding of its physicochemical properties, as these characteristics influence handling, storage, nutrient dynamics, thermochemical behaviour, and potential end uses [16].

Despite increasing interest in biomass valorization, limited information exists regarding the physicochemical characteristics of *Prosopis juliflora* biomass from semi-arid regions of Tamil Nadu. Such baseline information is essential before exploring advanced applications including biochar, biodegradable composites, and circular bioeconomy products.

Although ecological studies on *Prosopis juliflora* are abundant, information regarding the physicochemical characteristics of biomass collected from semi-arid regions of Tamil Nadu remains limited. Coimbatore District supports extensive populations of this species, particularly in disturbed habitats and marginal lands. Characterizing biomass from this region could contribute to future resource recovery initiatives and provide baseline information for sustainable management programmes [17].

Therefore, the present study aimed to evaluate selected physicochemical properties of *Prosopis juliflora* biomass collected from Coimbatore

District, Tamil Nadu, and to examine its potential for sustainable resource utilization within the broader context of circular bioeconomy principles and climate-responsive management [18].
Therefore, the objectives of the present study were to: (i) characterize selected physical, chemical, and mineral properties of Prosopis juliflora biomass collected from two locations in Coimbatore District; (ii) establish preliminary baseline information from a homogenized composite sample; and (iii) identify physicochemical characteristics that may guide future application-specific utilization studies.
(i) characterize the physicochemical properties of *Prosopis juliflora* biomass,
(ii) evaluate its potential as a sustainable biomass resource,
(iii) examine its relevance towards SDG 13.

## 2. MATERIAL AND METHODS

### 2.1 Study Area

The study was conducted in Coimbatore District, Tamil Nadu, India, which is characterized by a predominantly semi-arid climate and lies within the rain-shadow region of the Western Ghats. The district experiences high summer temperatures, moderate annual rainfall, and prolonged dry periods, providing favourable conditions for the establishment and proliferation of *Prosopis juliflora*. The species commonly occurs along roadsides, wastelands, water bodies, and peri-urban landscapes. Coimbatore District receives an average annual rainfall of approximately 650–700 mm, with a mean annual temperature of 27–28°C. The predominant soil types are red loamy and black cotton soils, which provide favourable edaphic conditions for the establishment and widespread distribution of *Prosopis juliflora* across degraded and semi-arid landscapes.

**Table 2.1:** Geographical coordinates of *Prosopis juliflora* biomass sampling sites in Coimbatore District, Tamil Nadu, India.

| Sampling Site ID | Location Context | Latitude | Longitude |
|---|---|---|---|
| CBE-01 | Sundarapuram-Kurichi Lake Area | 10.9579° N | 76.9882° E |
| CBE-02 | Karumathampatti- Park College Backyard Area | 11.1145° N | 77.1801° E |

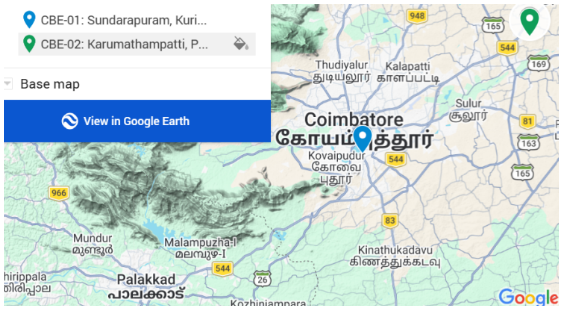


**Figure 2.1:** Location of *Prosopis juliflora* biomass sampling sites in Coimbatore District, Tamil Nadu, India.
**Source:** Google My Maps

### 2.2 Biomass Collection and Sample Preparation

Mature Prosopis juliflora individuals exhibiting well-developed woody characteristics were selected and harvested from both sampling locations. Approximately 5 kg of above-ground woody biomass was collected from each sampling location and pooled after processing. Collected materials were thoroughly washed with tap water followed by distilled water to remove adhering dust and extraneous materials.
The biomass samples were subsequently air-dried at ambient temperature (27–30°C) under laboratory conditions until constant weight was attained. Dried samples were mechanically ground and sieved to obtain particles of less than 0.5 mm. Equal proportions of processed biomass from both sampling sites were homogenized to prepare a composite sample prepared from the two selected sampling locations. The preparation of a composite sample was intended to establish baseline physicochemical characteristics for future multi-location investigations.

All physicochemical analyses were carried out as triplicate analytical measurements on the homogenized composite sample, and mean values were reported.

### 2.3 Physicochemical Characterization

#### 2.3.1 Determination of pH and Electrical Conductivity

The pH and electrical conductivity (EC) of the biomass samples were determined using a 1:10 biomass-to-distilled water suspension. The suspension was agitated thoroughly and allowed to equilibrate prior to measurement. pH was measured using a calibrated digital pH meter, while EC was recorded using an electrical conductivity meter and expressed as dS $m^{-1}$ [19,20].

#### 2.3.2 Bulk Density, Particle Density, and Porosity

Bulk density was determined by measuring the mass of oven-dried biomass occupying a known volume and expressed as g $cm^{-3}$ [20]. Particle density was estimated using the pycnometer method. Total porosity was calculated according to the following equation:

Porosity (%) = [1 – (Bulk density / Particle density)] × 100

### 2.3.3 Water-Holding Capacity
Water-holding capacity (WHC) was evaluated by saturating a known quantity of biomass with distilled water, draining excess water, and determining the increase in weight. WHC was expressed as a percentage of the dry biomass weight.

### 2.3.4 Organic Carbon and Nutrient Analysis
Organic carbon content was determined following the chromic acid wet oxidation procedure described by Walkley and Black. Total nitrogen was estimated by the Kjeldahl digestion method as described by Bremner and Mulvaney.

Available phosphorus content was quantified spectrophotometrically, whereas total potassium concentration was measured using a flame photometer. Calcium, magnesium, sodium, chloride, iron, and manganese contents were analysed according to standard procedures described by Jackson and the Association of Official Analytical Chemists (AOAC) [21, 22].

### 2.4 Statistical Analysis
All analytical measurements were performed in triplicate using the homogenized composite biomass sample, and mean values are reported. The triplicate measurements represent analytical replicates of the composite sample and should not be interpreted as independent biological or site replicates. The study was designed as a preliminary physicochemical characterization of biomass collected from two selected locations in Coimbatore District.

## 3. RESULTS
### 3.1 Physical Properties of *Prosopis juliflora* Biomass
The physical characteristics of the Prosopis juliflora biomass composite prepared from material collected at two locations in Coimbatore District are presented in Table 3.1. The biomass had a pH of 5.80 and an electrical conductivity of 0.65 dS $m^{-1}$. Bulk density and particle density were 0.25 and 1.00 g $cm^{-3}$, respectively, resulting in a calculated porosity of 75%. The biomass had a water-holding capacity of 220%.

### 3.2 Chemical Characteristics
Organic carbon content of the biomass was 45%, while total nitrogen was 0.98%. Available phosphorus was 30.0 mg $kg^{-1}$, and total potassium was 0.06%. These values describe the chemical composition of the composite biomass sample examined in this study.

### 3.3 Mineral Composition
The mineral profile of the composite biomass sample showed calcium as the major measured constituent at 14,990 mg $kg^{-1}$, followed by iron (1,200 mg $kg^{-1}$), sodium (780 mg $kg^{-1}$), magnesium (682 mg $kg^{-1}$), chloride (144 mg $kg^{-1}$), and manganese (8.5 mg $kg^{-1}$). Cadmium, chromium, nickel, and lead were below the instrumental detection limits under the analytical conditions used and are therefore not presented in Table 3.1.

The physical and chemical characteristics are summarized in Figure 3.1. Detailed values are presented in Table 3.1.

**Table 3.1:** Physicochemical composition of *Prosopis juliflora* biomass

| Parameter | Mean value (triplicate analytical measurements) |
|---|---|
| pH | 5.80 |
| Electrical Conductivity (dS $m^{-1}$) | 0.65 |
| Bulk Density (g $cm^{-3}$) | 0.25 |
| Particle Density (g $cm^{-3}$) | 1.00 |
| Water-Holding Capacity (%) | 220 |
| Porosity (%) | 75 |
| Organic Carbon (%) | 45 |
| Total Nitrogen (%) | 0.98 |
| Available Phosphorus (mg $kg^{-1}$) | 30.0 |
| Total Potassium (%) | 0.06 |
| Calcium (mg $kg^{-1}$) | 14,990 |
| Magnesium (mg $kg^{-1}$) | 682 |
| Sodium (mg $kg^{-1}$) | 780 |
| Chloride (mg $kg^{-1}$) | 144 |
| Iron (mg $kg^{-1}$) | 1,200 |
| Manganese (mg $kg^{-1}$) | 8.5 |

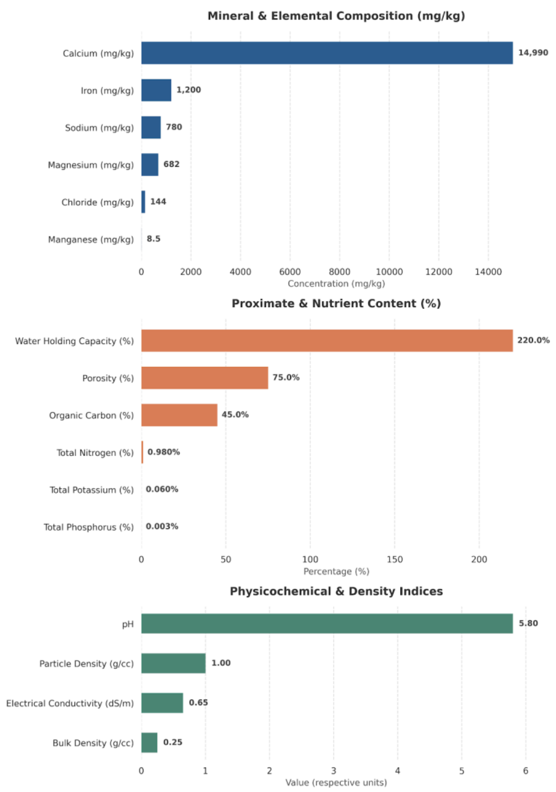


Figure 3.1: Physicochemical properties of Prosopis juliflora biomass from Coimbatore District, Tamil Nadu, India. The figure presents (A) mineral and elemental composition in mg $kg^{-1}$, (B) organic carbon and nutrient content, and (C) physicochemical and density indices. Values represent mean triplicate analytical measurements of the homogenized composite sample.

## 4. DISCUSSION

The biomass analysed in this study exhibited a moderately acidic pH and relatively low electrical conductivity. These observations suggest that the material contains limited amounts of soluble salts, which may be advantageous for applications where excessive salinity is undesirable [23,24,25]. Similar characteristics have been reported for biomass obtained from species adapted to semi-arid environments, where efficient regulation of ionic balance is considered an important survival mechanism under prolonged moisture stress [26].

One notable feature of the biomass was its ability to retain water. The measured water-holding capacity of 220% reflects the porous nature of the material and indicates its potential usefulness in applications such as composting, soil amendment, and moisture conservation. Such properties are often desirable in substrates intended to improve water availability in dryland conditions [27,28].

Bulk density and porosity are important factors affecting biomass transportation, storage, and processing. The low bulk density recorded in this study is consistent with the fibrous structure generally associated with woody biomass. High porosity may also facilitate gas exchange and improve accessibility during biological or thermochemical conversion processes [29].

The organic carbon content of 45% confirms that *Prosopis juliflora* biomass is predominantly composed of carbon-rich compounds. Biomass resources with substantial carbon content have received increasing attention because of their possible role in supporting sustainable resource management and circular bioeconomy initiatives [30]. Nitrogen, phosphorus, and potassium were present in measurable quantities, suggesting that processed biomass residues may possess agronomic value and could potentially contribute to nutrient recycling strategies. Previous studies have also reported the ability of *Prosopis juliflora* to influence soil nutrient dynamics and microbial communities [31,32].

Calcium represented approximately 1.5% of dry biomass, indicating its dominance among measured mineral constituents, followed by iron, sodium, and magnesium. The relatively high calcium concentration may be beneficial in maintaining buffering capacity and structural stability in biomass-derived products. The analysed heavy metals, including Cd, Cr, Ni, and Pb, were below the instrumental detection limits under the conditions employed in this investigation, indicating low metal contamination potential of the biomass. This observation is encouraging, although additional studies involving a larger number of sampling locations would be required before drawing broader conclusions regarding environmental safety.

Management of invasive alien plants often involves repeated removal efforts and substantial expenditure. Naturalization and spread of introduced species often create long-term management challenges. In this context, utilization of harvested biomass may represent a practical approach that combines ecological restoration with resource recovery [33,34]. Invasive biomass can also contribute to local livelihoods when harvested for fuel, fodder or products [35]. Effective management further requires stakeholder engagement and community participation [36]. International assessments have highlighted the need to link invasive species control with ecosystem service benefits [37]. Similar challenges have been reported for other invasive plants such as Lantana camara [38].

The present work was designed as a preliminary characterization study, and certain limitations should be acknowledged. Biomass samples from two locations were combined to obtain a composite sample, and only selected physicochemical parameters were evaluated. Future studies incorporating proximate analysis, calorific value estimation, lignocellulosic profiling, and thermochemical assessment would provide a more comprehensive understanding of the utilization potential of Prosopis juliflora biomass. Further assessment of impacts on soil properties and associated vegetation is also needed [39].

Detailed ecological and management guidelines for *Prosopis juliflora* should be consulted for planning large-scale utilization programs [40]. Such interventions can also be framed within the concept of novel ecosystems and restoration ecology [41].

Recent judicial directions in Tamil Nadu have also emphasized systematic management of *Prosopis juliflora* in ecologically sensitive regions [42]. National guidelines also provide frameworks for systematic management of invasive species in India [43].

The porous and carbon-rich nature of lignocellulosic biomass has attracted attention for the development of biodegradable and bio-based materials, thereby supporting circular resource utilization pathways [44].

Utilization of invasive biomass aligns with SDG-13 by supporting climate-resilient resource management through conversion of unmanaged biomass into value-added materials, thereby reducing dependence on conventional raw materials and promoting circular bioeconomy pathways.

## 5. CONCLUSIONS

The present investigation provides baseline information on the physicochemical characteristics of Prosopis juliflora biomass collected from two selected sampling locations of Coimbatore District, Tamil Nadu, India. The biomass exhibited moderately acidic pH, low electrical conductivity, high water-holding capacity, appreciable organic carbon content, and substantial concentrations of calcium and iron. The observed physicochemical properties indicate that harvested biomass possesses attributes that may support future applications involving biomass valorization, bio-based materials, nutrient recycling, and other sustainable resource utilization strategies.

The study further demonstrates that characterization of invasive biomass resources can contribute to the development of management approaches aimed at reducing ecological impacts while promoting productive utilization pathways. The observed low EC and nutrient profile indicate that future investigations may explore its suitability for soil amendment applications. Although additional investigations involving proximate analysis, lignocellulosic characterization, calorific value determination, and thermochemical assessment are necessary, the present findings establish a preliminary database for *Prosopis juliflora* populations occurring in Coimbatore District. Productive utilization of invasive biomass may complement ongoing management initiatives and support circular bioeconomy principles within the broader framework of climate-responsive resource management and Sustainable Development Goal 13 (Climate Action).

The generated dataset provides baseline information for future studies of biomass-derived products from Prosopis juliflora, including applications that require additional structural, thermal, and performance testing.

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