RESEARCH ARTICLE

Establishment of Regression Equation between the Herbaceous Cover and Herbage Carbon of Selected Plant Functional Types in a Dry Tropical Grassland of BHU, Varanasi

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Abstract

Grasslands are one of the largest carbon sinks and are crucial in the carbon cycle. However, modeling each species' carbon versus cover relationship is complex, and modeling ground flora covers of plant functional types simplifies the process. The present experiment randomly selected 115 quadrats of 1×1 meter square from the Banaras Hindu University campus, Varanasi, India. The cover of each herbaceous species was recorded by visual charting method and measured by gridding each 1×1 meter 'square' quadrat into 100 cells; each cell represented 1% cover. Species-wise, herbage carbon content was calculated. Species-wise, herbage carbon and cover were further categorized into different functional types. Prostrate, perennials, grasses, and native plants accumulate more carbon as compared to other plant species in grassland communities, which would help mitigate the menace of accelerating global warming issues. The established regression equation between plant cover and carbon content could be used at a worldwide scale for non-destructive estimation of carbon at functional group levels. Furthermore, non-destructive methods are superior to destructive methods in maintaining the diversity of tropical grassland because biomass harvesting can destroy the habitat spaces of rare and endangered species.

Keywords: Dry tropical grassland, Plant functional types, Herbaceous cover, Carbon, Regression equation.

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Introduction

In the present era of industrialization, the 50% increase in atmospheric carbon dioxide concentration since pre-industrialization has played a significant role in elevating greenhouse gas emissions (Letcher, 2020). Today's increase from 280 ppm in 1750 to 400 ppm is mainly attributed to anthropogenic activities like fossil fuel burning (Meinshausen *et al*., 2011). The rapid increase in atmospheric carbon dioxide has been predicted to reach 463–685 ppm by 2050, which results in accelerated climate change events like the elevated temperature of the earth, spatial and temporal variations in precipitation patterns, the problem of extreme weather conditions, and shifts in seasonal patterns (IPCC, 2021).

The increased concentration of carbon dioxide can modify various ecosystem processes and often creates the possibility for bulk sequestration of elevated carbon by the terrestrial biosphere through photosynthesis (Long *et al*., 2004). Plants can enhance the global gross primary productivity through photosynthesis; as a result, they fix an incredible amount of carbon, which is more than 20 times of carbon produced by burning fossil fuels (Field, 2001).

Grasslands are one of the largest sinks of carbon, storing approximately 34% of global carbon and containing 90% of plant species, still, there is a lack of sufficient studies on carbon estimation from tropical grasslands (White *et al*., 2000; Singh *et al*., 2006; Gilliam, 2007). The above-ground plant part is linked to the plant's photosynthetic tissue; therefore, removing the above-ground herbage cover reduces the plant's photosynthetic tissue, resulting in a loss of carbon and nutrients for the plant's growth and development as well as a reduction in herbaceous biomass (Ferraro and Oesterheld, 2002; Leriche *et al*., 2003). There are many methods employed for the estimation of carbon stored in different plant species, including field-based harvesting, remote sensing, regression equation, and carbon and biomass ratio (Yang *et al*., 2010; Piao *et al*., 2014; Sainju *et al*., 2017), but still, there is lack of precise and low cost, non-destructive method for carbon estimation in a tropical grassland.

The present study aims to establish a relationship between herbage cover and plant carbon of different plant functional types of tropical grassland. The specific objectives are:

- To estimate the herbage Carbon of different plant functional types.
- To calculate the herbaceous cover of different functional types.

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- To develop regression equations between the herbaceous cover and herbage carbon content for different herbaceous functional groups of the tropical grassland.

Material and Methods

Study Area

The study was conducted on the campus of Banaras Hindu University in Varanasi, India (25.3175° N latitude, 82.9739° E longitude, and 80.71 m above sea level), from November 2019 – February 2020. It has a tropical monsoon climate. There are three distinct seasons: warm rainy (July to September), hot summer (April to June), and cold winter (November to February). The transitional months are October and March (Verma *et al.*, 2015). The average maximum and minimum temperatures were 30.51 and 20.43°C, respectively, with an average annual rainfall of 969 mm. Alluvial, well-drained, silty loam and inceptisol describe the soil. It has a neutral to alkaline soil pH, low available nitrogen, medium available phosphorus, and medium available potassium (Sagar *et al.*, 2008).

Vegetation Sampling

For the experimental sampling of 115 quadrats, each of 1×1 m was randomly selected from the university campus. The cover of each herbaceous species was recorded by visual charting method and measured by gridding each 1×1 m quadrat into 100 cells of 10 cm × 10 cm cell; each represents 1% cover (Sagar *et al.*, 2008). Plants were categorized into different plant functional types like habit (prostrate and erect), life span (annual, biennial, and perennial), growth form (forbs, grasses, legumes, and sedges), and nativity (native and non-native). These traits were categorized according to Flora of Durg, Raipur, and Rajnandgaon (Verma *et al.,* 1985) and Flora of the upper Gangetic plain (Duthie, 1903).

Each species' cover was calculated and further categorized into different functional types. Species-wise, herbage carbon content was calculated using the carbon-to-biomass ratio available in the open literature (Verma *et al.*, 2019). Species-wise, herbage carbon content was further categorized into different functional types.

Statistical Analysis

Using Sigma Plot (12.5) software, various regression equations were derived and graphs were plotted.

Results

There were identified 69 herbaceous species from 28 distinct families. The majority of species belong to the Asteraceae family, while the 17 families contain only one species.

Poaceae, Asteraceae, and Fabaceae were the three families with the most species. Significant linear regression equations were found between the herbaceous cover and herbage carbon for different plant functional types (Fig. 1-2). In the habit plant functional type, prostrate plants occupied higher herbaceous cover (13.63%) and carbon (16.73 m^{-2}) than erect (6.85% Cover and 10.74 g C m^{-2}) (Table. 1). In the case of life span plant functional type, perennial plants showed comparatively higher herbage cover (10.79%) and herbage carbon content (14.34 g m^{-2}) than the annual (5.66% Cover and 9.42 g C m^{-2}) (Table 1).

Table 1. Average herbaceous cover (%) and average herbage carbon content (gm^{-2}), of different plant functional types in the dry tropical grassland. Values in parenthesis are SE.

Plant Functional types	Average cover (%)	Average carbon (gm^{-2})
Erect	6.85 ± 0.71	10.74 ± 1.27
Prostrate	13.63 ± 3.82	16.73 ± 5.39
Annual	5.66 ± 0.59	9.42 ± 1.47
Perennial	10.79 ± 1.79	14.34 ± 2.61
Grasses	12.96 ± 3.45	16.51 ± 4.71
Forbs	7.48 ± 0.80	12.04 ± 1.32
Legumes	4.58 ± 1.26	4.28 ± 1.89
Sedges	5.24 ± 0.95	4.31 ± 1.1
Native	9.17 ± 2.86	13.93 ± 4.46
Non-Native	7.63 ± 0.77	10.91 ± 1.19

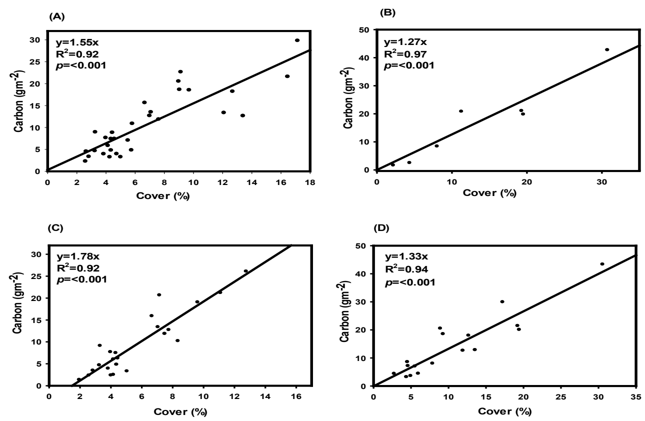

Fig. 1: Relationship between herbaceous cover (%) and herbage carbon content (gm^{-2}) for the selected plant functional types A) Erect, B) Prostrate, C) Annual, D) Perennial in the dry tropical grassland, Varanasi, India. R^2 and *p-value* represent the Coefficient of determination and Significance level, respectively.

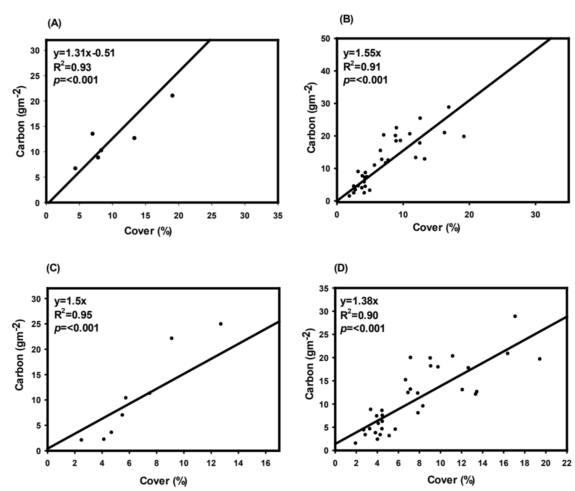

Fig. 2. Relationship between herbaceous cover (%) and herbage carbon content (gm^{-2}) for the selected plant functional types A) Grasses, B) Forbs, C) Native, D) Non-native in the dry tropical grassland, Varanasi, India. R^2 and *p-value* represent the Coefficient of determination and significance level, respectively.

In the Growth form plant functional type, grasses showed the highest herbaceous cover (12.96%) and carbon (16.51 g m^{-2}) than the forbs (7.48% Cover and 12.04 g C m^{-2}), sedges (5.24% Cover and 4.31 g C m^{-2}), and legumes (4.58% Cover and 4.28 g C m^{-2}) (Table.1). In the nativity plant functional type, the native had higher herbaceous cover (9.17%) and herbage carbon (13.93 g m^{-2}) than non-native (7.63% cover and 10.91 g C m^{-2}) (Table1). Erect, prostrate, annual, perennial, grasses, forbs, native and non-native plant functional types follow significant linear regression equations between percent cover and carbon (p=<0.05).

Discussion

In this experiment, in the habit plant functional type, the prostrate plants showed higher cover and carbon than erect plants, which could be due to the trailing nature of prostrate species. Prostrate plants occupy more area and cover will lead to more carbon content, but in contrast, in an experiment conducted in a tropical grassland, tall species had more biomass and carbon than prostrate and short-statured plants because of their high ability to capture carbon in the presence of sunlight (Sagar *et al.*, 2012; Verma *et al.*, 2015). Compared to annual plants, perennial plants were found to retain more carbon and cover, which may be explained by an excessive build-up of plant biomass in the form of sugars and many other chemical substances (Dickson, 1989). The plant might utilize this stored reserve material for their metabolism and survival throughout the dormant season because the current study location had a noticeable seasonality (Dickson, 1989). According to certain theories, perennials can sequester and store sufficient carbon throughout the growing season in seasonal conditions for them to endure the cold months and reappear in the following years (Farrar *et al.*, 2014).

In comparison to other growth form types, grasses contained considerably more carbon in the shoot than others due to comparatively higher carbon and biomass allocation in the above-ground component than below-ground, which has already been reported in tropical grassland (Verma *et al.*, 2019). Native plants show higher shoot carbon content and cover percentage so they could be a better option for carbon sequestration and climate change mitigation, which has also been reported (Verma *et al.*, 2019).

Modeling the relationship between carbon and cover for each species can be difficult, and species of the same functional type should have similar carbon/cover ratios (Rottgermann *et al.*, 2000; Muukkonen *et al.*, 2006; Porte' *et al.*, 2009). So, modeling ground plant covers based on plant functional types make model development easier and helps connect physiological strategies with ecosystem dynamics (Chapin, 1993).

Conclusion

Comparatively larger carbon in perennials, prostrate, grasses, and native plant functional types than others suggested that species with these traits could be employed to reduce atmospheric CO_2 by absorbing and converting it into biomass through photosynthesis. The linear regression equation obtained between herbage carbon and herbaceous cover might be utilized to estimate carbon at the functional type level without disturbing the diversity and biomass in the grassland ecosystem. Furthermore, biomass harvesting has the potential to harm the habitat spaces of rare and endangered species, making non-destructive ways superior to destructive methods in conserving the diversity of tropical grassland.

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Author's Contributions

Ram Sagar conceptualized the idea and designed the experiment. Alka Gupta, Aakansha Pandey, and Kajal Singh performed the experiment and collected data. Alka Gupta analyzed the data. Alka Gupta and Aakansha Pandey drafted the manuscript and Prof. R. Sagar corrected it. All the authors have critically read the drafted manuscript and approved it for publication.

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