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Assessing the Impact of Human-Induced Disturbances on the potential Biomass and Carbon content in two wildlife sanctuaries of Uttar Pradesh, India

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ABSTRACT

This research paper presents a detailed analysis of biomass assessment of woody species in Katerniaghat and Kaimoor Wildlife Sanctuary situated in Bahraich and Mirzapur district of Uttar Pradesh. Through a reconnaissance survey, area was stratified into high, medium and low disturbed site based on the presence of human induced disturbance indicators. Circular plot method of 10m radius was used for vegetation assessment. Data on vegetation like woody species name, number of individuals, Girth at Breast's height were recorded. Biomass and carbon stock of tree species was calculated from each stratified site of both sanctuaries. The finding of the study showed that highest biomass was estimated from high disturbed site of Katerniaghat. In Kaimoor, medium disturbed site showed maximum biomass. The present study aims to provide a comprehensive understanding of its carbon stock and sequestration potential. Biomass assessment is crucial for sustainable forest management and climate change mitigation strategies. Our findings reveal the negative impact of varying levels of anthropogenic disturbance on the forest biomass of both protected areas and help in better understanding of conservation and management and forests and carbon offset initiatives.

Key words : *Tree species biomass assessment, Carbon stock, Anthropogenic disturbance, Sustainable forest management,*

Introduction

A forest ecosystem is an area comprised of complex heterogeneous vegetation. The vertical stratification of forests exhibits distinct layers or strata, each inhabited by different species adapted to specific environmental conditions and resource availability. The uppermost layer of a forest is composed of mature trees that form a dense leafy cover, shading the forest floor below. The layer beneath the canopy consists of smaller trees, shrubs, saplings, and herbaceous plants that receive filtered sunlight. The lowest layer is characterized by organic matter, leaf litter, soil, and diverse microorganisms, fungi, and invertebrates. Forest ecosystems vary greatly in their composition, structure, and function depending on factors such as climate, soil type, topography, and disturbance history. In India, forests were classified by Champions and Seth in 1968 based on rainfall and temperature data (Senthilkumar *et al.*, 2014). Tropical forests play a vital role in supporting biodiversity, regulating climate, providing ecosystem services, sustaining human livelihoods, sequestering atmospheric carbon dioxide (CO2) through photosynthesis and storing it in biomass; therefore, a major contributor to net primary production

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(Dietze *et al.,* 2014; Schlesinger and Bernhardt, 2013).

Forest biomass refers to the total mass of living organisms, including trees, shrubs, herbs, and other vegetation, as well as organic matter present in soils and litter. Forest biomass can vary greatly depending on factors such as forest type, age, climate, soil fertility, disturbance history, temperature, precipitation, and sunlight availability influencing photosynthesis rate and carbon sequestration. Tropical rainforests, for example, have high biomass potential due to warm temperatures, abundant rainfall, and year-round growing seasons. Different tree species have varying growth rates, biomass allocation patterns, and ecological niches. Forests with diverse species composition often exhibit higher biomass accumulation due to niche complementarity, resource partitioning, and facilitative interactions among species. Mixed-species forests may also be more resilient to environmental stressors and disturbances. Larger woody species make an unreasonably large contribution to the forest's biomass and production (Wangtedonk *et al.,*2010; Bastin*et al.,* 2015; Lutz *et al.,* 2018; Bradford *et al.,* 2019; Enquist *et al.,* 2020; Mensah *et al.,* 2020; Ali *et al.,* 2021, Bisht *et al.,* 2022).

Forest biomass has significant carbon sequestration potential, with trees and vegetation acting as carbon sinks that absorb and store atmospheric carbon dioxide (CO_2). Maximizing the carbon sequestration potential of forests can help mitigate climate change by offsetting carbon emissions from human activities (Biswas *et al.,* 2009; Duarte *et al.,* 2013). Sustainable forest management practices that promote forest conservation, afforestation, and reforestation can enhance the carbon storage capacity of forests and contribute to climate change mitigation efforts. Sustainable management practices that promote forest regeneration, tree planting, and selective harvesting can enhance biomass productivity and carbon sequestration while maintaining ecosystem health and biodiversity. Conversely, unsustainable practicesand extensive anthropogenic disturbance such as logging and overgrazing reduce biomass potential and degrade forest ecosystems.

Accurate assessment of forest biomass is essential for understanding carbon dynamics, evaluating forest health, and designing effective climate change mitigation strategies. Indian forests are a significant ecosystem with diverse flora and fauna, making it imperative to assess its biomass and carbon stock comprehensively. Different types of methods have been implied for biomass estimation of forests. Indirect estimation methods like field measurements, remote sensing, and modeling approaches (Brahma *et al.,* 2021), provide valuable information on forest productivity, carbon stocks, and ecosystem dynamics. Direct methods, also known as harvest method, are expensive especially when sampling a larger area accompanied by variety of woody species (Gibbs *et al.,* 2007; Sileshi, 2014). Forest managers use biomass data to assess forest health, monitor changes over time, and inform management decisions aimed at conserving biodiversity, enhancing ecosystem services and promoting sustainable use of forest resources. Vashum and Jayakumar (2012) reviewed an overview of different methods used to estimate the above-ground biomass of forests and carbon stocks.

The main objective of the present study was to assess the carbon potential and biomass estimation of forests in context to varying magnitudes of anthropogenic disturbance present in selected wildlife sanctuaries of Uttar Pradesh. Understanding the complex interactions between human activities and forest carbon dynamics is essential for informed decision-making and sustainable forest management practices.

Study Area

Katerniaghat Wildlife Sanctuary

The sanctuary is located in the Bahraich district of Uttar Pradesh, India, at GPS coordinates 28°06'N & 28°24'N latitude and 81° 02É 81° 19'É longitude (Figure 1), and covers an area of 400 square kilometres. The sanctuary is situated on the upper Gangetic plain's alluvium soil. This area has three distinct climates: summer, winter, and monsoon. The rivers present here are Girwa, Kauriayala, Ghaghra, and Saryu. The forest type found in the sanctuary is tropical moist deciduous. The sanctuary is divided into three types of habitats, according to Champion and Seth's (1968) classification: sal forest, miscellaneous forest, and grasslands. *Shorea robusta, Aegle marmelos, Scleicheraoleosa, Adina cordifolia, Tectona grandis, Sacchrummunja, Phragmites karka,* and *Calamus tenuis* are among the most common plants found in the area. The sanctuary is surrounded by a diverse wildlife population. Six settlements are located within the sanctuary, whereas more than 100 communities can be found on the outskirts (Anonymous, 2000).

Fig. 1. Map of India showing location of Katerniaghat (Inset: Uttar Pradesh), Source: Tahoor, 2017

Kaimoor Wildlife Sanctuary

The sanctuary is located in the Mirzapur and Sonbhadra districts of Uttar Pradesh, India, with GPS coordinates 82< 20’15’’E to 24< 52’00’’N and 82< 08’23’’E to 24< 27’51’’N (Figure 2), covering an area of 500 sq.km. The refuge is built on red clay in an undulating steep area. The entire area has three seasons: summer, winter, and monsoon. The rivers here are Son and Belan. The area is surrounded by dry deciduous forest (Champion and Seth Classification, 1968) and is classified into three principal habitats: Sal forest, bamboo forest, scrub forest, and deciduous forest. The sanctuary’s floral species *include Madhuca indica, Buchanania lanzan, Diospyros melanoxylon, Nyctanthus arbortristis,* and *Cynodondactylon*. In addition, the sanctuary is home to a diverse range of mammals. Eighteen settlements are located within the sanctuary, with populations of 30350 people and 22004 cattle (Chandra, 2010).

Methodology

With the help of a reconnaissance survey, both the study area was stratified into high, medium and low

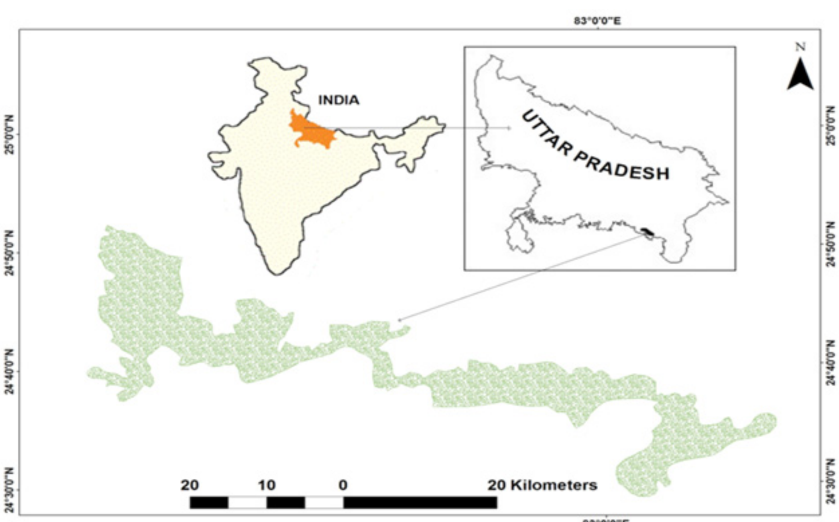

Fig. 2. Map of India showing location of Kaimoor (Inset: Uttar Pradesh), Source: Tahoor, 2017

disturbed site depending upon the distinct human-induced disturbance indicators like human trail, lopping/logging, grazing and weed cover. Three sites were chosen following consultations with forest officials, locals, and personal observations. Data on diverse anthropogenic variables such as human paths, logging, weeding, and grazing were obtained at each of the three locations using an 0-4 scale/indexing system. Tree lopping was categorized as: 0=no lopping, 1= rudimentary signs of lopping, 2= half of the main branches lopped, 3=more than half of the main branches lopped and 4= complete tree is a stump. Human trail was categorized on 0-4 scale as: 0= no trail, 1= 1 foot trails, 2 =2 foot trails, 3= 3 foot trails and 4=4foot trails. The weed and grazing cover were indexed as: 0=no grazing, 1=1-25% of grazing, 2=26-50% of grazing, 3=51-75% of grazing and 4=76-100% of grazing. From each circular plot, the value of each disturbance variable was added to give a common index value. Then the averaged index for each of the stratified site was calculated. The calculated mean index value helped in identifying and designating areas into high, medium and low disturbed site. Following area stratification, data collection was started. For vegetation assessment, circular plot method (10 m radius) was used. In each three stratified sites, transects were laid randomly having circular plots stationed at an equal distance of 200m. From each circular plot; the number of individuals of tree and its species, girth at breast's height and tree height was recorded. Woody species whose GBH>30cm and height>3m was considered as tree (Mueller-Dombois and Ellengergh, 1974). A total of 162 and 198 circular plot were laid in the three categorized sites of Katerniaghat and Kaimoor respectively. For data analysis, forest biomass were estimated following Ravindranath *et al.,* (1995); Ravindranath and Ramakrishnan (1997)

Biomass estimation of each tree species (M)=(8.32*BA)-1.69

Where, Basal Area (BA)= πr^2, r=radius of circular plot

Carbon stock= M/2

Results and Discussion

Table 1 showed the estimated biomass of different species recorded during data collection circular plot method in Katerniaghat. Where only eighteen species were recorded from high disturbed site. The finding of the present study showed that Adina cordifolia was found to be having highest biomass (2389814) followed by *Syzizium cumunii* (1103351). Meanwhile, the lowest estimated was of *Zizyphus mauritiana* (445.821). In medium disturbed site, a total of twenty species were recorded. Out of 20 recorded species, the highest estimated biomass was of *Terminalia alata* (12350.44) followed by *Ficus glomerata* (8254.75). The least estimated biomass was of Unidentified species2 (292.8994). Twenty four tree species were recorded from low disturbed site. The highest estimated biomass was of *Scleicheraoleosa* (5632.912) and *Terminalia arjuna* (5343.288). The least biomass estimated from low disturbed sites was of *Helicterisisora* (51.9319) and *Terminalia tomentosa* (51.9319). A total of thirty four species showed their contribution towards total biomass estimation from the sanctuary. The overall values of estimated biomass showed that high disturbed site from Katerniaghat supports maximum biomass (3676590) followed by medium and low disturbed site (43050.77 and 27332.84 respectively). The relationship between anthropogenic disturbance and forest biomass is complex and can vary depending on the type and intensity of the disturbance, as well as the resilience of the forest ecosystem. In some cases, disturbances such as logging or clearing for agriculture can result in a significant reduction in forest biomass, as trees and other vegetation are removed. This can have detrimental effects on biodiversity, carbon storage, and ecosystem services provided by forests. Similarly, forest biomass of Katerniaghat was estimated to largerly from high disturbed site it showed that that if same magnitude of human induced disturbance will be continued in the future, it will affect the rare and endangered species present in that area. Lin *et al*., (2015) also documented that different types of anthropogenic disturbance affect the biomass of forests by altering the wood stand and density. Similarly, Tahoor *et al*., (2021) found the impact of anthropogenic disturbance on the Importance Index Values (IVI) of different species, where the tree dominance is one of the important parameter and is calculated by measuring the Girth at Breast's height.

Table 2 showed the estimated biomass of different species recorded during data collection circular plot method in Kaimoor. From high disturbed site of sanctuary, total of thirteen species were recorded. The highest estimated biomass was of *Butea monosperma* and *Ficus benghalensis* (626027 and 195702 respectively). From medium disturbed site, eleven species were recorded. The highest estimated biomass of *Cassia fistula* and *Shorea robusta* (5899896 and 1262994 respectively). The least estimated biomass of *Terminalia arjuna* (4671.76). From least disturbed site, a total of twenty two species were recorded. The highest estimated biomass of *Bambusa arundinacea* and *Diospyros melanoxylon* (961034 and 593882, respectively). The least estimated biomass of Makoicha (3910.17). Whereas, a study had been conducted in an unprotected landscape of Vindhyan range by Mishra *et al.,* 2020 documenting that *Delonix regia* representing with maximum biomass. However, Tahoor *et al*. (2016) concluded that the anthropogenic disturbance effect the IVI of recorded species from the forests of Kaimoor, where tree dominance plays a major role. Similar findings were documented by Feliciy *et al.* (2022), where the tree diversity, structure and carbon stock are negatively affected by anthropogenic disturbance. A total of thirty species were recorded from Kaimoor wildlife sanctuary that contributed towards the overall biomass estimation. The medium disturbed site of sanctuary supports highest biomass (7456525) followed by low and high disturbed (1956053 and 1197339 respectively).

The findings highlight the importance of integrating multiple methods for biomass assessment to account for spatial variability and uncertainty. Field measurements provide accurate biomass data at plot scales but may not capture the entire forest

Table 1. Above ground biomass estimation of woody species in Katerniaghat

S.No.	Common Name	Scientific name	High	Medium	Low
1	Dalbergia	*Dalbergia sissoo*	7952.099	2365.22	929.2457
2	Bel	*Aegle marmelos*	2221.663	1653.307	
3	Ber	*Zizyphusmauritiana*	445.8211		
4	Bhilor	*Terminalia alata*	3855.583	12350.44	2770.43
5	Gular	*Ficus glomerata*	13264.25	8254.758	718.5104
6	Haldu	*Adina cordifolia*	18694.04	2490.073	675.6174
7	Jigna	*Lannea grandis*	2389814	1630.137	2071.318
8	Katgular	*Ficus hispida*	8756.332	488.2959	399.8122
9	Khair	*Acacia catechu*	2910.167	494.7375	545.8066
10	Kusum	*Schliecheraoleosa*	4584.637		5632.912
11	Mallotus	*Mallotusphillipinenses*	3254.738		807.4151
12	Menda	*Litseasebifera*	19130.07		290.2514
13	Shorea	*Shorea robusta*	25465.06		
14	Teak	*Tectona grandis*	1298.231	672.142	1228.442
15	Casia	*Cassia tora*		1195.535	
16	Chamrodh				306.5532
17	Guava	*Psidium guajava*			189.6276
18	Semal	*Bombax ceiba*	39930.45	2651.325	1504.113
19	Sihor	*Streblus asper*	6618.297	1337.74	417.3138
20	Syzyzium	*Syziziumcumunii*	1103351	1497.761	625.3883
21	Khaja	*Bridelia retusa*			1120.729
22	Lasod	*Chordia dichotoma*			212.7976
23	Marod	*Helicterisisora*			51.9319
24	Imlilkleavs	*Cassia semia*			634.4908
25	Karipatta				170.4297
26	Karwat	*Terminalia tomentosa*			51.9319
27	Tikui	*Terminalia arjuna*		391.4269	5343.288
28	Rohini	*Mallotusphillipineneses*		631.9956	
29	Prash	*Lagerstroemia parviflora*		3118.475	
30	Junglee neem	*Murayyakoenigii*		689.4367	634.4908
31	Kadakpatti	*Sterculia villosa*		375.4085	
32	Unidentified 1		25044.37		
33	Unidentified 2			469.6531	
34	Unidentified 3			292.8994	
	Total		3676590	43050.77	27332.84

Table 2. Above ground Biomass estimation woody species inKaimoor

S.No.	Tree species	Scientific names	High	Medium	Low
1	Asna	*Terminalia elleptica*	3126.66	3526.61	84176.4
2	Babool	*Acacia nilotica*	6267.67		
3	Bamboo	*Bambusaarundinacea*	195702	60720.1	961034
4	Bargad	*Ficus benghelenses*	98364.3	36320	15782
5	Mahua	*Madhuca indica*	38343.5	57593.7	6618.3
6	Palash	*Bute monosperma*	626027	6135.6	11093.3
7	Peepal	*Ficus religiosa*	140077	59578.2	2302.73
8	Sal	*Shorea robusta*	5264.32	1262994	9353.35
9	Semia	*Cassia semia*	5674.15		
10	Tendu	*Diospyros melanoxylon*	63798.9		593882
11	Harsinghar	*Nyctanthesarbortristis*	2970.02		
12	Chilbil	*Holoptelia integrifolia*	3729.29		
13	Gulmohar	*Delonix regia*	7993.94		
14	Semal	*Bombax ceiba*		58337.5	12018.2
15	Amaltas	*Cassia fistula*		5899896	
16	Arjun	*Terminalia arjuna*		4671.76	
17	Rewa			6751.36	
18	Kathmaula	*Bauhinia purpurea*			5361.16
19	Khair	*Acacia catechu*			19238.2
20	Kurayya				16334.2
21	Makoicha				3910.17
22	Neem	*Azadirachta indica*			14839.1
23	Rimjim				15824.6
24	Sagon	*Tectona grandis*			14071.7
25	Siddhi				4303.02
26	Siras				6953.6
27	Kaima				15362.5
28	Bahera	*Terminalia bellerica*			11887
29	Chironji	*Buchananialanzan*			124119
30	Jigna	*Adina cordifolia*			7588.26
	Total		1197339	7456525	1956053

landscape. Remote sensing techniques offer a broader perspective but rely on assumptions and calibration with ground data. Model-based approaches complement both field and remote sensing methods by extrapolating biomass estimates across larger spatial scales.

Table 3 showed the estimated potential carbon present in woody species of Katerniaghat and Kaimoor Wildlife Sanctuary. The overall carbon present in the forest of Katerniaghat and Kaimoor were found to be 1873487.025 and 5304958.185 respectively. In Katerniaghat, the highest carbon presence was calculated from high followed by medium and low disturbed areas of the sanctuary (21525.4 and 13666.42 respectively). In Kaimoor, medium disturbed area of sanctuary supports maximum carbon presence (3728262.41) followed by low and high disturbed areas (978026.4 and 598669.3 respectively).

Table 3. The estimated potential carbon present in the forests of Katerniaghat and Kaimoor Wildlife Sanctuary

	Katerniaghat	Kaimoor
High	1838295.217	598669.375
Medium	21525.38606	3728262.415
Low	13666.42242	978026.395
Overall	1873487.025	5304958.185

Understanding the synergies and trade-offs between biomass dynamics and human activities is crucial for designing effective strategies for sustainable forest management and climate change mitigation. Sustainable management practices that minimize disturbance while promoting ecosystem health and resilience are essential for maintaining and enhancing forest biomass in the face of human activities. This research paper provides a comprehensive assessment of biomass in the forests of Katerniaghat and Kaimoor using field measurements. The study enhances a better understanding of carbon dynamics and ecosystem processes in context to anthropogenic disturbance in the forest ecosystem. The findings contribute to informed decision-making for sustainable forest management and climate change mitigation strategies.

Conflict of Interest

All three authors have no conflict of interest to declare.

References

Ali, A. and Wang, L.Q. 2021. Big-Sized Trees and Forest Functioning: Current Knowledge and Future Perspectives. *Ecol. Indic*. 127: 107760.

Anonymous, 2000. Management Plan for Katerniaghat Wildlife Sanctuary, Wildlife Preservation Organization Forest Department, Lucknow, 2000: 201.

Bastin, J.F., Barbier, N., Réjou-Méchain, M., Fayolle, A., Gourlet-Fleury, S., Maniatis, D., De Haulleville, T., Baya, F., Beeckman, H. and Beina, D. 2015. Seeing Central African Forests through their Largest Trees. *Sci. Rep*. 5: 13156.

Bisht, S., Bargali, S.S., Baragali, K., Rawat, G.S., Rawat, Y.S. and Fartyal, A. 2022. Influence of anthropogenic activities on forest Carbon stocks- a case study from Gori Valley, Western Himalaya. *Sustainability.* 14: https://doi.org/10.3390/su142416918

Biswas, S.R., Mallik, A.U., Choudhury, J.K. and Nishat, A. 2009. A unified framework for the restored of Southeast Asian mangroves- Bridging ecology, society and economics. *Wetl. Ecol. Manag*. 17: 365-383.

Bradford, M. and Murphy, H.T. 2019. The Importance of Large-Diameter Trees in the Wet Tropical Rainforests of Australia. *PLoS One.* 14: e0208377.

Brahma, B., Nath, A. J., Deb C., Sileshi, G.W., Sahoo, U.K. and Das, A.K. 2021. A critical review of forest biomass estimation equations in India. *Trees, Forests and People*. 5, https://doi.org/10.1016/j.tfp.2021.100098.

Chandra, S. 2010. Management Plan for Kaimur Wildlife Sanctuary. Wildlife Preservation Organization Forest Department, Lucknow 98 p.

Dietze, M.C., Sala, A., Carbone, M.S., Czimczik, C.I., Mantooth, J.A., Richardson, A.D. and Vargas, R. 2014. Non-structural carbon in woody plants, *Annu. Rev. Plant Biol*. 65: 667-687.

Duarte, C.M., Losada, I.J., Hendriks, I.E., Mazarrasa, I. and Marbà, N. 2013. The role of coastal plant communities for climate changemitigation and adaptation. *Nat. Clim. Chang*. 3: 961-968.

Enquist, B.J., Abraham, A.J.,Harfoot, M.B.J., Malhi, Y. and Doughty, C.E. 2020. The Megabiota Are Disproportionately Important for Biosphere Functioning. *Nat. Commun*. 11: 699.

Felicity, B., Frederick, G.D., Alexander, N.M.P., Bernard, E. and Hugh, K.A. 2022. Impact of anthropogenic disturbance on tree species diversity, vegetation structure and carbon storage potential in an upland evergreen forest of Ghana, West Africa. *Trees, Forests and People.* 8: *https://doi.org/10.1016/j.tfp.2022.100238.*

Gibbs, H.K., Brown, S., Niles, J.O. and Foley, J.A. 2007. Monitoring and estimatingtropical forest carbon stocks: Making REDD a reality. *Environ Res Lett.* 2: 1-13.

Lin, D., Lai, J., Yang, B., ong, P., Ning, L. and Haibo, R.K. 2015. Forest biomass recovery after different anthropogenic disturbances: relative importance of changes in stand structure and wood density. *EurJ For Res*. 134: 769-780,https://doi.org/10.1007/s10342-015-0888-9

Lutz, J.A., Furniss, T.J., Johnson, D.J., Davies, S.J., Allen, D., Alonso, A., Anderson-Teixeira, K.J., Andrade, A., Baltzer, J. and Becker, K.M.L. 2018. Global Importance of Large-Diameter Trees. *Glob. Ecol. Biogeogr*. 27: 849-864.

Mensah, S., Noulèkoun, F. and Ago, E.E. 2020. Aboveground Tree Carbon Stocks in West African Semi-Arid Ecosystems: Dominance Patterns, Size Class Allocation and Structural Drivers. *Glob. Ecol. Conserv*. 24: e01331.

Mishra, N.N., Biswaroop, M. and Umrao, R. 2020. Assessment of Biomass and Carbon Stocks in *Delonix regia* speciesin Vindhyas Series. *Int J Curr Microbiol Appl Sci.* 11: 2512-2517.

Ravindranath, N.H. and Rmakrishan, J. 1997. Energy cooking options in India. *Energy Policy* 25(1): 63-75, https://doi.org/10.1016/S0301-4215(96)00105-X

Schlesinger, W.H. and Bernhardt, E.S. 2013. Chapter 5- The Biosphere: The Carbon Cycle of Terrestrial Ecosystems. In: *Biogeochemistry: An Analysis of Global Change*, 3rd Edition, Academic Press, Boston, MA, USA, 135–171.

Sethilkumar, N., Prakash, S., Kannan, C.R., Prasath, A.A. and Krishnakumar, N. 2014. Revisiting forest types of India (Champion and Serh, 1968): A case study of Myristica swamp forest in Kerala. *Int J Adv Res.* 2(2): 492-501

Sileshi, G.W. 2014. A critical review of forest biomass estimation models, common mistakes and corrective measures. *For. Ecol. Manag*. 329: 237-254.

Tahoor, A., Musavi, A. and Khan, J.A. 2016. Biomass extraction impact on vegetation community structure in Kaimur Wildlife Sanctuary, Uttar Pradesh, India. *Tropical Plant Research*. 3(1): 142-152

Tahoor, A., Musavi, A. and Khan, J.A. 2021. An ecological assessment of anthropogenic disturbance impact on regeneration and Importance Values Index of woody species in Katerniaghat Wildlife Sanctuary. *International Journal of Environmental and Ecology Research.* 3(2): 15-21

Vashum, K.T. and Jayakumar, S. 2012. Methods to Estimate Above-Ground Biomass and CarbonStock in Natural Forests - A Review. *J Ecosyst Ecography.* 2:116. doi:10.4172/2157-7625.1000116.