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Original Article

Ecological studies and Carbon Stock Assessment of Secondary Forests in Kashung , Kamjong, Manipur Post-Shifting Cultivation

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Abstract

The study was made to understand the natural ecological healing process through quadrat method, biomass and carbon stock assessment of the forest following allometric equations post shifting cultivation in Kamjong district, Manipur. The study identified 52 species across 32 genera under 24 families. In which, *Bambusa spp.* (5000/ha) was the most abundant with a significant density of 50.2, contrasting sharply with the least presence of Rhododendron spp., which had only 150 individuals/ha. Relative abundance assessments further confirmed *Bambusa spp.* as the dominant species within the studied area, with a relative abundance value of 4.577% as oppose to species such as *Rhododendron spp*. and *Pinus kesiya* showed considerably lower relative abundances, 0.274 and 0.292, respectively, suggesting their minor contribution to the overall biomass. The study also highlights the uniformity of the Diameter at Breast Height (DBH) sizes due to the young age of the secondary forest. The analysis delineated the ecological roles of various species as reflected in their Importance Value Index (IVI), with key species like *Tectona grandis* (24.958) and *Cinammom tamala* (11.50) contributing significantly to the forest structure. Finally, the assessment of biomass and carbon content revealed a total biomass at 1975.3 tonnes/ha and carbon stock estimated at 987.6 tonnes/ha, emphasizing the ecological importance of the forest. Notably, *Bambusa spp*. contributed the highest carbon stock at 44.71 tonnes/ha, wherein the correlation between carbon content and the total number of individual species was significant, indicating a structured ecological relationship. The findings underscore the richness and ecological intricacies of the forest habitat, marking it as a critical area for conservation and ecological studies.

Keywords: Quadrat study, relative dominance, abundance, IVI, biomass, and Carbon content.

Introduction

Shifting cultivation is a primitive form of agriculture that is believed to have started approximately 7000 B.C. during the Neolithic era (Tiwari & Pant, 2018). Unfortunately, the need for food security and economic development in remote part of world has led to an increased emphasis on such agricultural practices that either directly or indirectly resulted in forest depletion. According to reports, jhum cultivation is responsible for 60% of annual forest losses globally (Lele & Joshi, 2008). Over 8.5 million tonnes of phytomass, including forest floors, are burned annually as a result of this practice (Choudhury *et al.*, 2015).

The problem gets intensified with extreme erosion from steep slopes with a massive loss of plant cover and top fertile soils as the bare soil can no longer hold itself together. It is projected that at an erosion rate of 40–80 t/ha/year, about 30% of the region is classified as badly degraded (Mandal & Sharda, 2013).

It demands for a minute understanding on the ecosystem post-shifting cultivation which may vary from one geographical location to another under different sets of environmental conditions. With respect to shifting cultivation, the role and information of the secondary forests is often side-lined that plays a crucial role in the restoration of carbon-stocks.

The vast abandoned area after the harvesting season serves as a bed that transforms the landscape into secondary forests within a significant gap of time. Thus, the newly emerged forests functioned as a rekindled mechanism of carbon sequestration and biodiversity conservation. This transformative process is not an uncommon process especially in Northeast India, including the state of Manipur. One of the most pressing challenges of shifting cultivation in Manipur is rapid environmental degradation. While this method is central for growing various crops in hilly terrains, it also leads to significant deforestation and habitat loss (Rungsung, 2024). Studies have hinted that the reduction of fallow periods—from the traditional 15-20 years to as little as 2-3 years—compromises the forest's ability to recover (Tamuli & Bora, 2022). This shortened cycle exacerbates soil erosion, depletes soil fertility, and contributes to the loss of biodiversity. Consequently, the regenerative capacity of the land is diminished, leaving the ecosystem vulnerable to climate-related challenges.

However, majority of studies on the shifting cultivation were done on the issues and challenges posed to the environment, whereas, a very limited study have been carried out aftermath shifting cultivation to the area where it is left unattended for a longer period.

Methodology

Study site

Kashung village is located within Kamjong District (Fig. 1a, & b), one of the newer districts of Manipur formed in 2016, presents an unique blend of geographical, cultural, and socio-economic characteristics that make it an intriguing area for study. It lies within the Lat 24° 44' 50.64" N, and Long 94° 18' 55.44" E with a minimum and maximum temperature of 3º C to 33° C. The average annual rainfall is approximately between 1,600 mm and 2,100 mm. The forest area covers 24.3 sq. km. The present study was undertaken during August to October 2024 to understand the ecological dynamics, biomass, and standing carbon stock of major species within the secondary forest of Kashung village post shifting cultivation with a gap of 15 years.

Ecological studies

The present study employed the methodologies for conducting entire ecological analyses using 10x10 meter quadrats specifically aimed at measuring density, frequency, Importance Value Index (IVI), basal area, (Mishra 1968). 15 random quadrats were laid on the entire stretch of the forest wherein 3 quadrats were laid in close proximities to bring a more accurate result of the study. Thereby maintaining at least of 1 km 5 groups of such quadrats were studied. Other sizes of quadrat were not employed with limited time study. However it is important to know that the use of a 10x10 meter quadrat also provide sufficient opportunity to collect robust and representative samples of vegetation in a defined area, facilitating the analysis of plant abundance and diversity. Identifications of the plants were made using colloquial names, and the specimens' identities were ascertained by consulting regional flora and published literatures (Hooker, 1887; Singh *et al.*, 2000; Ningombam, 2014).

Biomass and Carbon estimation

The biomass of the tree species was estimated using diameter at breast height (DBH) measurements, applying the allometric equations developed by Brown (1997) for wet forest ecosystems. Biomass values were expressed in kg ha^{-1}. Carbon stock was subsequently calculated following the widely accepted assumption that approximately 50% of the dry biomass represents carbon content (Brown, 1997; Beets et al., 2012; IPCC, 2003; Ravindranath & Ostwald, 2008).

Results

Species Distribution

The total number of species documented was 52 belonging to 32 genera and represented by 24 families. The entire enumeration of the study is given in Table no. 1 and number of family representation is shown as an illustration marked as Fig. 1b.

Highest number of family is represented by *Fabaceae* and *Meliaceae* (6 each) followed by *Anacardiceae* and *Lauraceae* (4 each), *Fagaceae* and *Moraceae* (3 each), *Lamiaceae, Magnoliaceae, Malvaceae*, *Phyllanthaceae*, *Pinaceae*, *Salicaceae* (2 each) and least was observed in *Apocynaceae, Araliaceae, Auriculariaceae, Betulaceae, Ericaceae, Euphorbiaceae, Lythraceae, Myrtaceae, Poaceae, Rutaceae, and Theaceae* represented by single species.

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Fig. 1a. Map showing study site

Fig. 1b. Study within the Kashung forest

From all the quadrat studies, the highest total number of individuals was recorded in *Bambusa spp.* with 251 individuals, and thus dominated the study area. On the other hand, *Rhododendron spp*. had only 15 total individuals that might indicate a limited spread or distribution in the observed quadrats. The highest density was obtained by *Bambusa spp*. at 50.2, pointing out its significant abundance over the region meanwhile the lowest density was reported in Rhododendron spp. at 3.0, indicating sparse distributions. Frequency indicates the percentage of quadrats in which a species appeared.

Many species had a frequency of 100%, meaning they were present in the studied quadrats signifying their overall presence within the forest, such as *Bambusa spp*., *Bischofia javanica*, and *Alnus nepalensis*. This means that these species are spread out and evenly distributed. Some species, like *Pinus kesiya* and *Magnolia champaca*, showed a lower frequency (40% or 80%), which reflects a more restricted presence. Raunkiaer's frequency class distribution diagram is given as Fig no. 2 in which Class E (59.6%) showed the highest percentage followed by D (32.6%), C and B (both 3.8%) classes meaning all the documented species had found a very suitable fertile environment for their rich growth that was left after shifting cultivation. Most species with a frequency of 100% had a relative frequency of 2.146, which further confirmed the observation made above of an equal contribution in the uniformly present species category. It's also important to mention species like *Auricularia delicata* and *Cinnamomum verum* had relatively lower values (e.g., 1.717), which corresponds to their limited distribution across quadrats.

Relative abundance gives information about the dominance of species by comparing each species count to the total individuals of all species. The species that has the highest relative abundance was *Bambusa spp*., 4.577 (Table 1). It further affirmed its dominance ecologically in the studied area. Species such as Rhododendron spp. and *Pinus kesiya* recorded very low relative abundances, 0.274 and 0.292, respectively. They have least amount of contribution to the total biomass.

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Table no. 1. Species recorded with ecological parameters

Sl.No.	Plant species	Family	Total no. of indiv (S)	Density	Freq %	Freq class	Relative freq	Relative abund	Relative Domin	IVI
1	*Alnus nepalensis*	Betulaceae	156	31.2	100	E	2.146	2.845	0.190	5.181
2	*Albizzia procera*	Fabaceae	164	32.8	100	E	2.146	2.991	0.199	5.335
3	*Albizzia lebbeck*	Fabaceae	131	26.2	100	E	2.146	2.389	1.212	5.746
4	*Toona ciliata*	Meliaceae	175	35	100	E	2.146	3.191	2.535	7.872
5	*Melia azaderach*	Meliaceae	96	19.2	100	E	2.146	1.751	0.153	4.049
6	*Quercus pachyphylla*	Fagaceae	59	11.8	80	D	1.717	1.076	1.160	3.952
7	*Quercus dealbata*	Fagaceae	98	19.6	80	D	1.717	1.787	0.806	4.310
8	*Artocarpus spp.*	Moraceae	76	15.2	80	D	1.717	1.386	0.381	3.484
9	*Pinus kesiya*	Pinaceae	16	3.2	40	B	0.858	0.292	2.716	3.866
10	*Castanopsis hystrix*	Fagaceae	120	24	100	E	2.146	2.188	0.615	4.949
11	*Bischofia javanica*	Phyllanthaceae	187	37.4	100	E	2.146	3.410	5.356	10.912
12	*Bambusa spp.*	Poaceae	251	50.2	100	E	2.146	4.577	1.242	7.965
13	*Rhododendron spp*	Ericaceae	15	3	60	C	1.288	0.274	0.042	1.603
14	*Cedrela serrata*	Meliaceae	74	14.8	80	D	1.717	1.349	0.289	3.355
15	*Xylosma sps.*	Anacardiaceae	191	38.2	100	E	2.146	3.483	2.555	8.184
16	*Ficus hispida*	Moraceae	149	29.8	100	E	2.146	2.717	0.869	5.732
17	*Holiadrana longifolia*	Apocynaceae	107	21.4	100	E	2.146	1.951	0.395	4.492
18	*Phyllanthus emblica*	Phyllanthaceae	18	3.6	80	D	1.717	0.328	1.533	3.578
19	*Machilus villosa*	Lauraceae	94	18.8	100	E	2.146	1.714	1.194	5.054
20	*Melia azaderach*	Meliaceae	91	18.2	100	E	2.146	1.659	0.113	3.919
21	*Cinnamomum tamala*	Magnoliaceae	25	5	80	D	1.717	0.456	9.335	11.508
22	*Magnolia spp.*	Magnoliaceae	107	21.4	80	D	1.717	1.951	1.828	5.496
23	*Pterospermum acerifolium*	Malvaceae	75	15	80	D	1.717	1.368	0.039	3.124
24	*Rhus sinensis*	Anacardiaceae	55	11	80	D	1.717	1.003	0.752	3.472
25	*Sterospermum chelonoides*	Bignoniaceae	106	21.2	80	D	1.717	1.933	1.769	5.419
26	*Phoebe hainesiana*	Lauraceae	38	7.6	80	D	1.717	0.693	2.955	5.365
27	*Duabanga sonneratiodes*	Lythraceae	47	9.4	80	D	1.717	0.857	0.037	2.611
28	*Aglaia spectabilis*	Meliaceae	74	14.8	60	C	1.288	1.349	8.639	11.276
29	*Gmelina arborea*	Lamiaceae	68	13.6	100	E	2.146	1.240	0.618	4.004
30	*Spondias pinnata*	Anacardiaceae	108	21.6	80	D	1.717	1.969	0.262	3.948
31	*Albizia stipulata*	Fabaceae	129	25.8	100	E	2.146	2.352	0.815	5.313
32	*Tectona grandis*	Lamiaceae	124	24.8	100	E	2.146	2.261	20.551	24.958
33	*Salix tetrasperma*	Salicaceae	104	20.8	100	E	2.146	1.896	0.157	4.199
34	*Schima wallichii*	Theaceae	86	17.2	100	E	2.146	1.568	0.415	4.129

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35	*Syzgium cuminii*	Myrtaceae	105	21	100	E	2.146	1.915	0.464	4.524
36	*Spondias mangifera*	Anacardiaceae	152	30.4	100	E	2.146	2.772	0.830	5.748
37	*Pinus wallichiana*	Pinaceae	19	3.8	40	B	0.858	0.346	2.716	3.920
38	*Ficus rumphii*	Moraceae	161	32.2	100	E	2.146	2.936	3.945	9.026
39	*Bauhinia purpurea*	Fabaceae	195	39	80	D	1.717	3.556	2.514	7.786
40	*Magnolia champaca*	Lauraceae	86	17.2	100	E	2.146	1.568	1.845	5.560
41	*Bauhinia scandens*	Fabaceae	59	11.8	80	D	1.717	1.076	0.006	2.799
42	*Enchiingok(local name)*		117	23.4	100	E	2.146	2.133	0.001	4.281
43	*Anil(local name)*		124	24.8	100	E	2.146	2.261	0.007	4.414
44	*Entada gigas.*	Fabaceae	100	20	100	E	2.146	1.823	1.566	5.535
45	*Xylosma spp.*	Salicaceae	91	18.2	100	E	2.146	1.659	2.494	6.299
46	*Auricularia delicata*	Auriculariaceae	175	35	100	E	2.146	3.191	0.000	5.337
47	*Azadirachta indica*	Meliaceae	115	23	100	E	2.146	2.097	2.809	7.052
48	*Cinnamomum verum*	Lauraceae	117	23.4	80	D	1.717	2.133	2.807	6.657
49	*Zanathoxylum alatum*	Rutaceae	152	30.4	100	E	2.146	2.772	0.025	4.943
50	*Hevea brasilensis*	Euphorbiaceae	197	39.4	100	E	2.146	3.592	0.120	5.858
51	*Aralia armata*	Araliaceae	70	14	100	E	2.146	1.276	3.844	7.266
52	*Bombax ceiba*	Malvaceae	35	7	80	D	1.717	0.638	2.281	4.636

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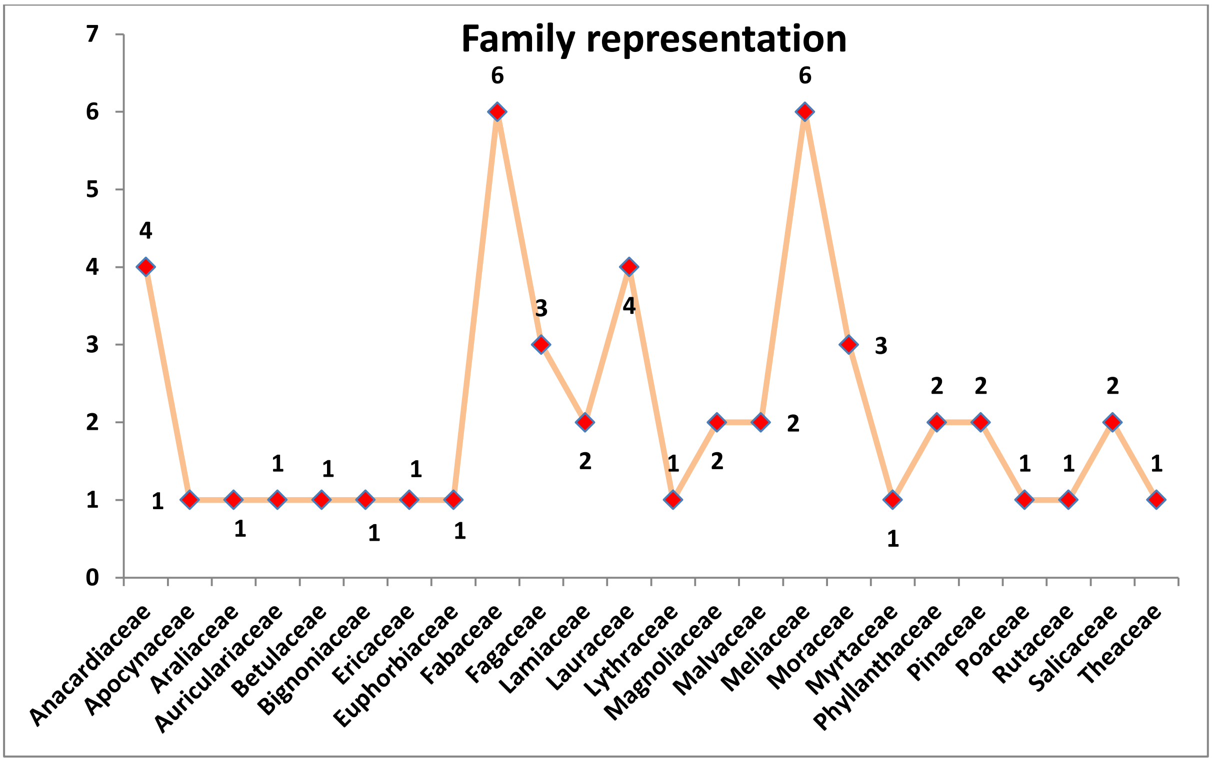

Fig 1b. Graph showing family numbers of the all the documented species

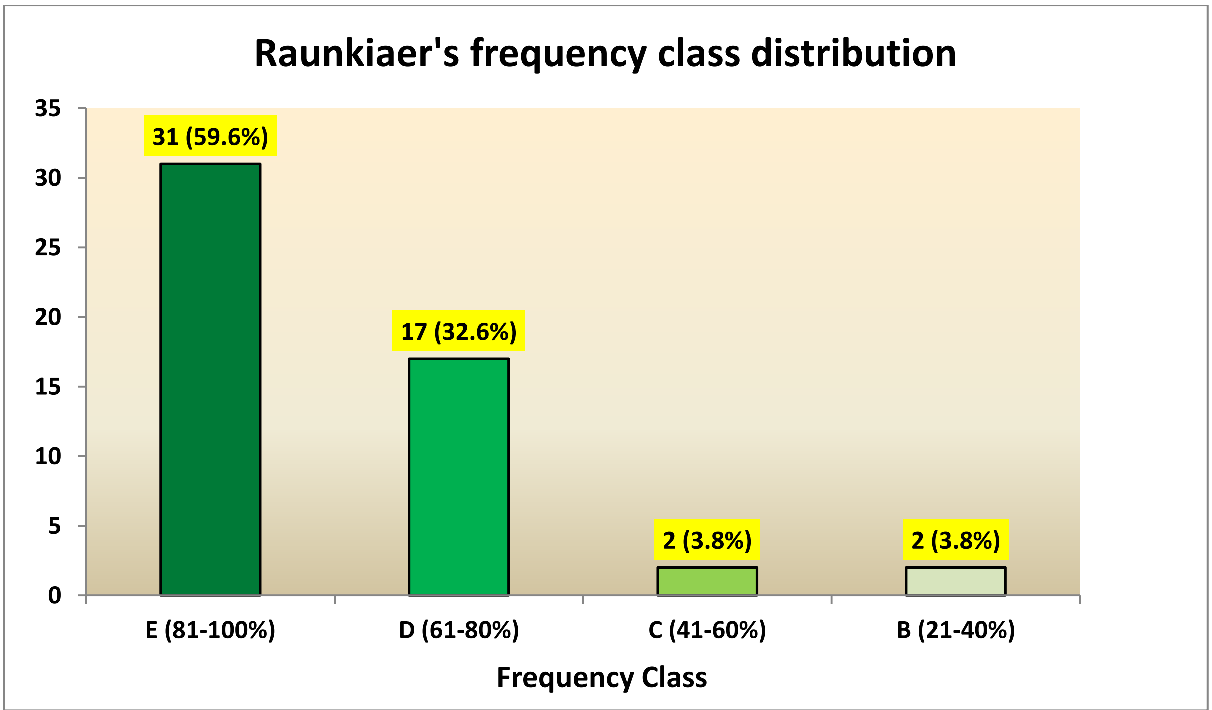

Fig. 2. Raunkiaer's frequency class distribution

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DBH, basal area, relative dominance and IVI

There were more or less uniform dbh of all the species with very less fluctuation in sizes (Fig. 5.) considering that the secondary forest started rejuvenating from only last 10 to 15 years post shifting cultivation. The five largest dbh were recorded from *Tectona grandis* (257.5cm) *Cinammom tamala* (174.4cm), *Bischofia javanica* (133.34 cm) *Ficus rumphii* (113.3cm) and *Aralia armata* (111.8cm) with respective total basal areas of 5280.2 m^2, 2398 m^2, 1376 m^2, 1013 m^2 and 987 m^2. As a by-product of above, the total relative dominance of all the species exhibited the same pattern and is presented in Table no. 1.

Present study observed that the major tree species occupying the Kashung forest were *Tectona grandis* (24.958) *Cinammom tamala* (11.50), *Aglaia spectabilis* (11.27), *Bischofia javanica* (10.91), *Ficus rumphii* (8.18), *Xylosma sps.* (8.18), *Bambusa spp.* (7.96), *Toona ciliata* (7.87), *Bauhinia purpurea* (7.78), and *Aralia armata* (7.26) with the highest IVI(s) and minor tree species were *Pinus wallichiana* (3.920) *Melia azaderach* (3.919), *Pinus kesiya* (3.866) *Emblica officinalis* (3.578), *Artocarpus spp.* (3.484) *Rhus sinensis* (3.472), *Cedrela serrate* (3.355), *Pterospermum acerifolium* (3.124) *Bauhinia scandens* (2.799) *Duabanga sonneratiodes* (2.611), and *Rhododendron spp.* (1.60) with lowest IVI. The total ranking of the IVI of all the species recorded is given in the Table no. 2 and its strong correlation with relative dominance (r = 0.93) and milder relation with relative abundance (r = 0.30) is also presented in Fig. no. 6.

Table no. 2. IVI rank

Rank	Species	IVI
1	*Tectona grandis*	24.958
2	*Cinnamomum tamala*	11.508
3	*Aglaia spectabilis*	11.276
4	*Bischofia javanica*	10.912
5	*Ficus rumphii*	9.026
6	*Xylosma sps.*	8.184
7	*Bambusa spp.*	7.965
8	*Toona ciliata*	7.872
9	*Bauhinia purpurea*	7.786
10	*Aralia armata*	7.266
11	*Azadirachta indica*	7.052
12	*Cinnamomum verum*	6.657
13	*Xylosma spp*	6.299
14	*Hevea brasilensis*	5.858
15	*Spondias mangifera*	5.748
16	*Albizzia lebbeck*	5.746
17	*Ficus hispida*	5.732
18	*Magnolia champaca*	5.560
19	*Entada gigas.*	5.535
20	*Magnolia spp.*	5.496
21	*Sterospermum chelonoides*	5.419
22	*Phoebe hainesiana*	5.365
23	*Auricularia delicata*	5.337
24	*Albizzia procera*	5.335
25	*Albizia stipulata*	5.313
26	*Alnus nepalensis*	5.181
27	*Machilus villosa*	5.054
28	*Castanopsis hystrix*	4.949

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29	*Zanathoxylum alatum*	4.943
30	*Bombax ceiba*	4.636
31	*Syzgium cuminii*	4.524
32	*Holiadrana longifolia*	4.492
33	*Anil(local name)*	4.414
34	*Quercus dealbata*	4.310
35	*Enchiingok(local name)*	4.281
36	*Salix tetrasperma*	4.199
37	*Schima wallichii*	4.129
38	*Melia azaderach*	4.049
39	*Gmelina arborea*	4.004
40	*Quercus pachyphylla*	3.952
41	*Spondias pinnata*	3.948
42	*Pinus wallichiana*	3.920
43	*Melia azaderach*	3.919
44	*Pinus kesiya*	3.866
45	*Phyllanthus emblica*	3.578
46	*Artocarpus spp.*	3.484
47	*Rhus sinensis*	3.472
48	*Cedrela serrata*	3.355
49	*Pterospermum acerifolium*	3.124
50	*Bauhinia scandens*	2.799
51	*Duabanga sonneratiodes*	2.611
52	*Rhododendron spp.*	1.603

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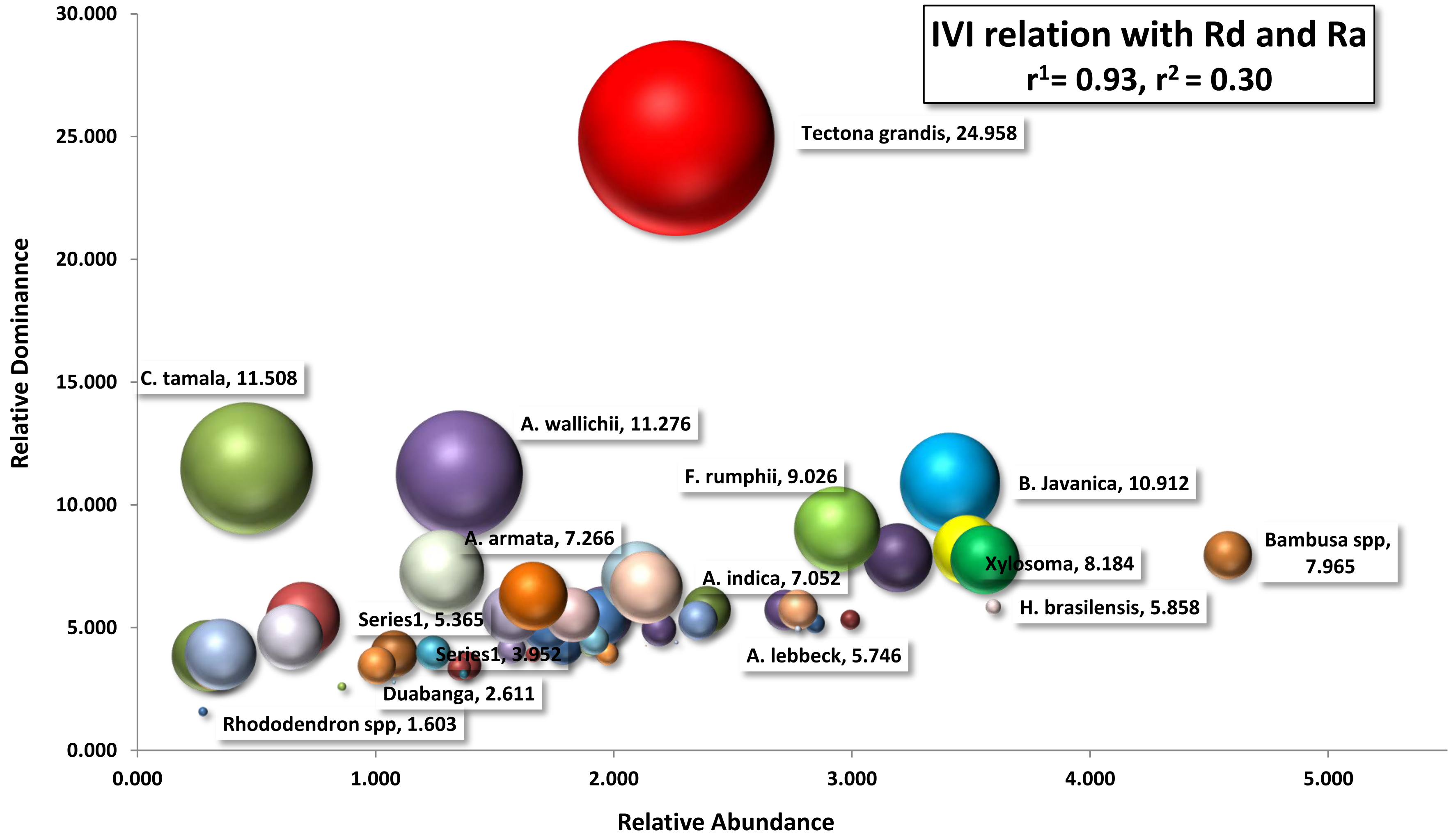

Fig.6. Relationship between IVI of the plants and relative dominance (r =0.93) and relative abundance (r = 0.30)

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Biomass and Carbon

Biomass and total Carbon content per hectare of all the studied species are presented in Table no. 3. Total biomass were 1975.3 tonnes/ha whereas the total carbon were estimated at 987.6 tonnes/ha. The total carbon stock of the studied forest is also illustrated in fig no. 7 in which, *Bambusa spp*. showed with the highest net contribution (44.71 tonnes/ha) and *Pinus kesiya* (2.58 C tonnes/ha) with the lowest involvement. A regression between logarithm of carbon content and total number of species individuals were plotted and a significant (R^2= 0.93) value were computed (Fig. no. 8). Fig. no. 9 depicts the representative amount of carbon stock present in the forest with that of carbon footprint left by number of person globally considering 4 tones is produced by an average person.

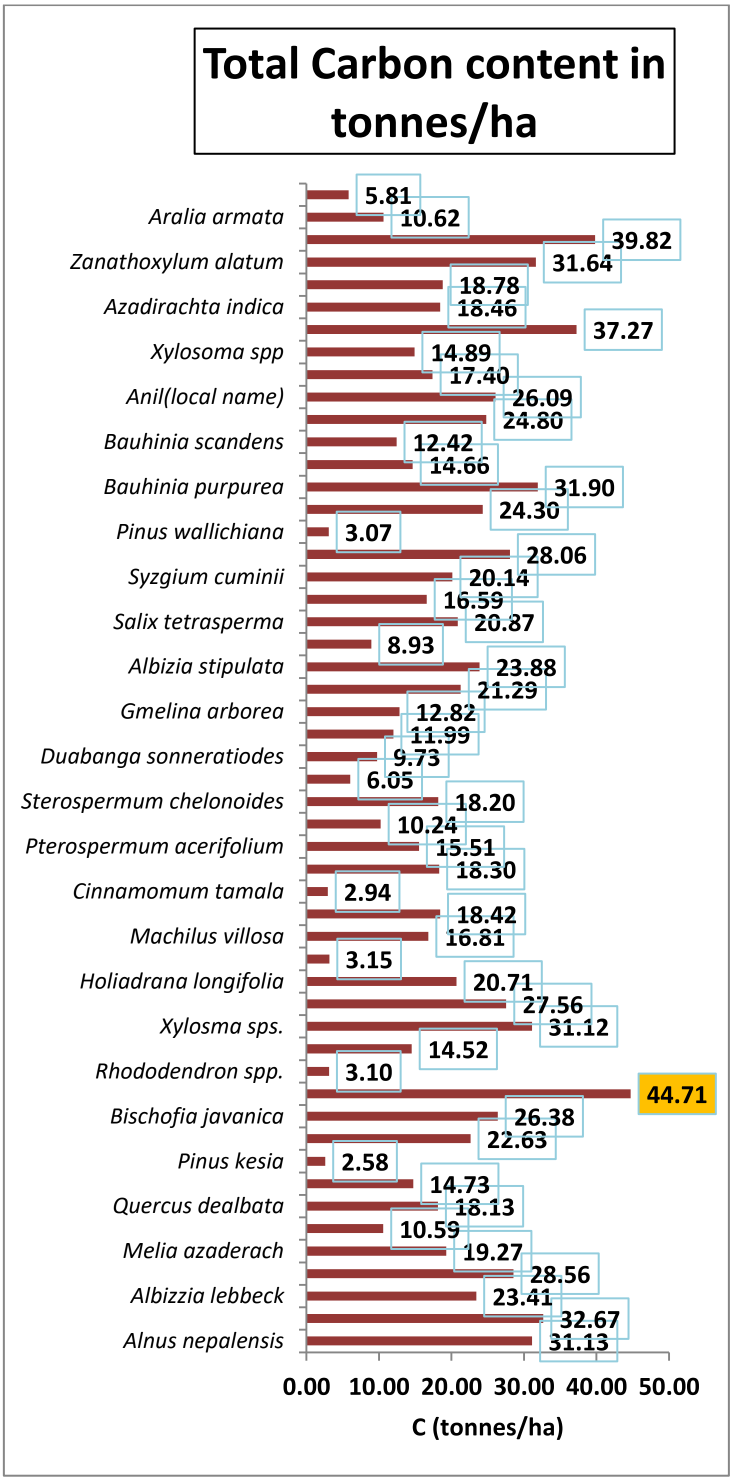

Fig. 7. Estimated Carbon stock of Kashung forest in

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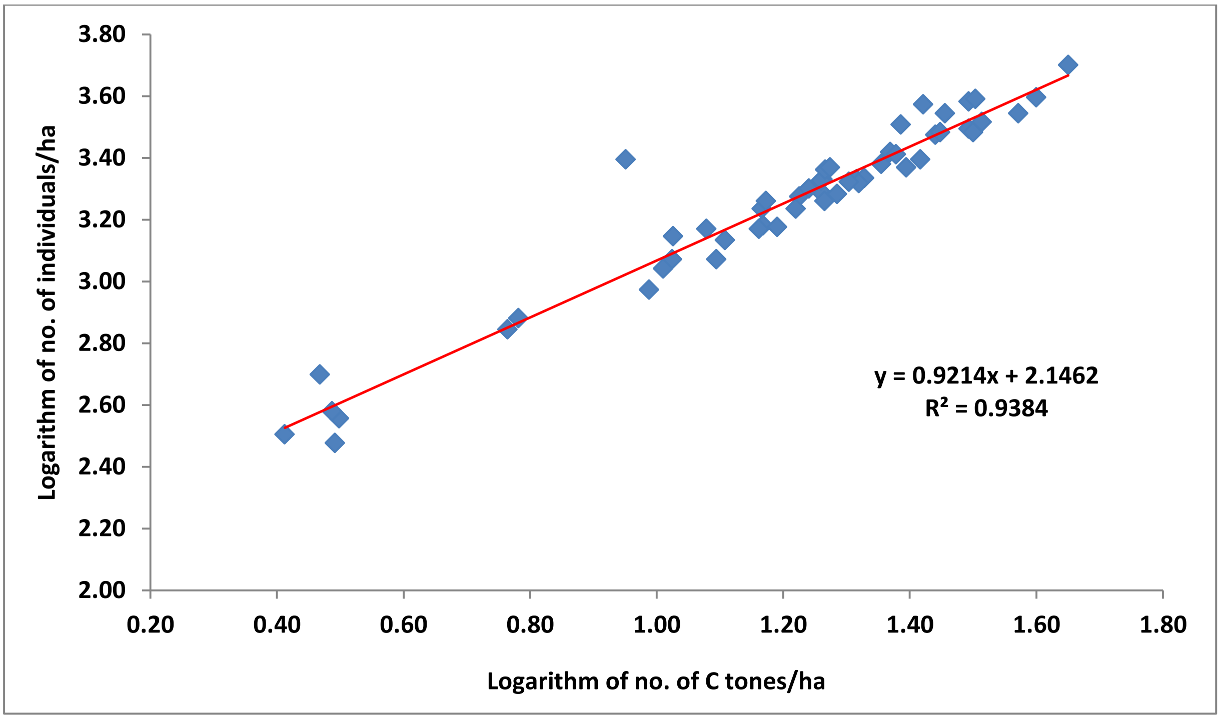

Fig. 8. Regression between total number of individuals/ha and total number of C tonnes/ha in Kashung forest

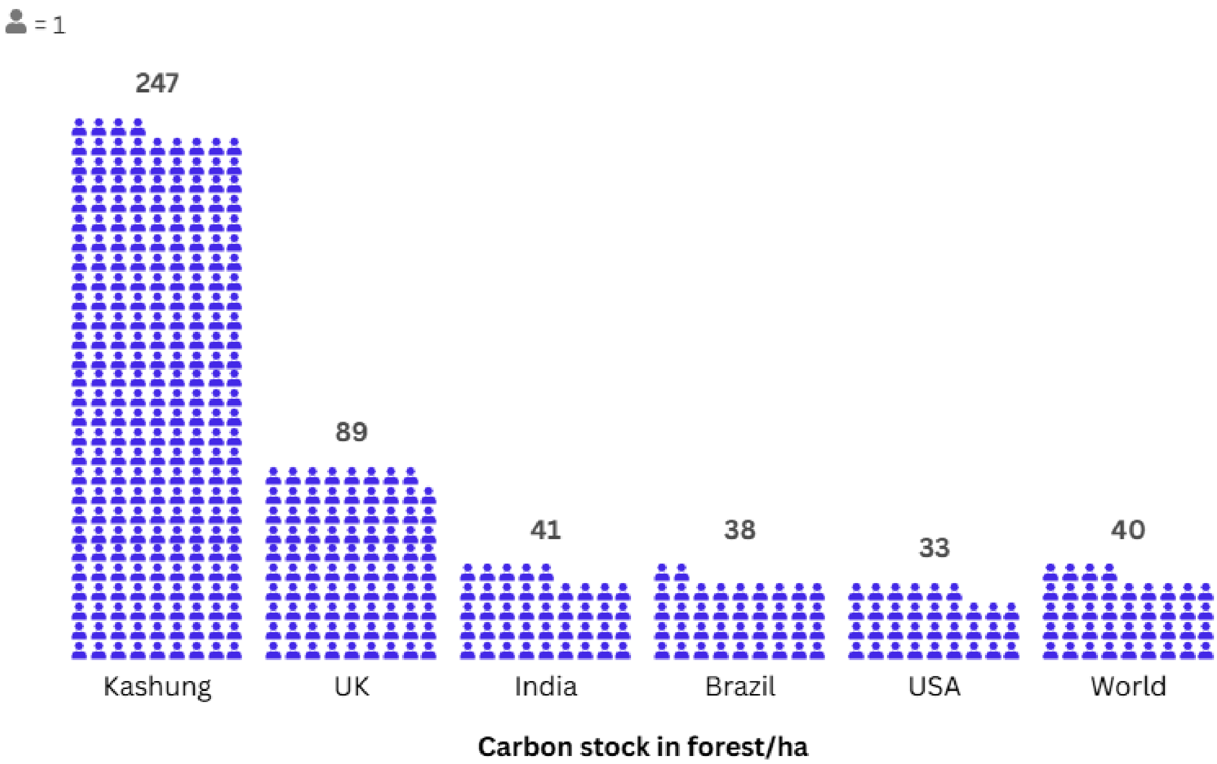

Fig. 9. Carbon footprints by aprox. no. people compare to the different forest and study site per hectare

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Discussions

The data reveals the presence of a diverse array of plant species, each contributing uniquely to the overall ecological balance and functionality of the forest. Considering the age of the forest and luxuriant growth of species, it offers an insight of the possible competition seral stage on a fertile landscape which is also substantiated by the findings of Tilman (1994), Huston and Smith (1987).

One of the key insights from the data is the significant variation in the relative frequency, abundance, and dominance of the plant species. Certain species, such as *Tectona grandis*, *Cinnamomum tamala*, and *Aglaia spectabilis*, exhibit remarkably high relative dominance, indicating their dominating influence on the overall structure and composition of the forest community. This finding aligns with the observation that a few common species concentrated in a few higher taxa can dominate vast areas of tropical forests, challenging the prevalent notion of Amazonian vegetation as a small-scale mosaic of unpredictable composition and structure (Pitman *et al.,* 2001). Species like Rhododendron spp., *Phyllanthus emblica*, and *Magnolia champaca* have low frequencies and relative abundances and also have low densities. This could be the case because of specific requirements by habitat, competition from other dominant species, or even from anthropogenic factors.

At the same time, the data also reveals the presence of rarer species, such as *Rhododendron spp*. and *Bauhinia scandens*, which contribute to the overall biodiversity and ecosystem resilience. These rare species, despite their lower relative frequency and abundance, may play a crucial role in the functional diversity and resource acquisition of the forest community.

The information given reflects the distribution and abundance of various plant species spread across all the quadrats studied. It highlights crucial ecological metrics including density, frequency, relative frequency, and relative abundance; these are crucial for gaining insight into the species' composition, diversity, and dominance within the surveyed area.

The examination of biomass and carbon content is critical for understanding forest contributions to carbon storage and climate regulation. The calculated data indicate an impressive total biomass of 1975.3 tonnes per hectare and a total carbon content of 987.6 tonnes per hectare within the studied forest ecosystem, highlighting its significant role in carbon sequestration. These figures reflect the essential ecological services provided by forests, including carbon storage, which is crucial for mitigating climate change.

Bambusa spp. with a notable net contribution of 44.71 tonnes of carbon per hectare which were notably higher the previous studies (Holly *et al,* 2020; Sultanova *et al.,* 2023;) This figure emphasizes the species' effectiveness in sequestering carbon compared to others in the ecosystem. Conversely, *Pinus kesiya* exhibited a meager carbon storage rate of only 2.58 tonnes per hectare (Weiskopf, *et al*. 2024). This stark contrast underscores the differences in biomass allocation and carbon capture capabilities among various tree species, likely influenced by factors such as growth rates, biomass density, and ecological adaptations. The significantly higher carbon contribution from *Bambusa* spp. can also be attributed to their rapid growth and resource utilization efficiency, often resulting in a high aboveground biomass.

The implications of these findings are essential for forest management and conservation strategies. By identifying species like *Bambusa* spp. that are particularly effective at carbon sequestration, forest management practices can be optimized to enhance carbon stock (Lorenz & Lal, 2009). This could involve promoting the growth of species that show higher carbon storage potential while managing those species that contribute less, like *Pinus kesiya*. Furthermore, the data can inform reforestation and afforestation projects aimed at maximizing carbon capture in future forest ecosystems, aligning with global initiatives for emission reductions (UNECE, 2023).

The regression value computed ($R^2 = 0.93$) between the logarithm of carbon content and the total number of individual species indicates a robust relationship. This high correlation suggests that as the number of individual species increases, the carbon content per hectare also tends to rise significantly (Harris *et al*., 2021). It highlights the importance of species diversity in enhancing carbon storage capabilities within forest systems. Such findings align with biodiversity theory, which posits that diverse ecosystems tend to be more productive and resilient, enhancing their functional capacity, including carbon sequestration (Lorenz & Lal, 2009).

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The data presents a compelling narrative emphasizing the importance of both species composition and diversity in contributing to forest biomass and carbon storage (Gao et al, 2014). The results advocate for strategic forest management that prioritizes species capable of significant carbon capture, which is paramount in efforts to combat climate change. This approach not only aids in understanding the ecological dynamics of the forest studied but also positions it as a vital component in global carbon management efforts.

Conclusion

This study presents compelling evidence of the ecological dynamics at play within the Kashung forest. The calculation of biomass revealed a total of 1975.3 tonnes per hectare, further underpinned by a carbon stock estimate of 987.6 tonnes per hectare. Notably, *Bambusa* spp. made the most significant contributions to carbon sequestration, elucidating its ecological importance in mitigating climate impacts. The strong correlation between the Importance Value Index (IVI) and relative dominance emphasizes the role of these major species in shaping the forest structure and biodiversity resilience.

In essence, this study not only enriches our understanding of species interactions and ecological roles within the Kashung forest ecosystem but also illustrates the broader implications for conservation strategies aimed at preserving biodiversity and ecological integrity in the face of anthropogenic pressures. Future research efforts should endeavor to explore the dynamics of the less represented species while assessing the impact of environmental changes on the observed community structure to foster an adaptive management approach.

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