Structure and Floristic Composition of Existing Agroforestry Systems in Allahabad District of Uttar Pradesh, India

Abstract

The study on the Structure and Floristic Composition of Agroforestry Systems was conducted in the agricultural fields of Kashari village (site-I) and Korihar village (site-II) in Allahabad District, Uttar Pradesh, India, from 2008 to 2010. Quantitative characteristics of the vegetation were assessed using the quadrat method. Floristic diversity was examined through random sampling, with 20 quadrats of 10m x 10m each. Parameters such as density, frequency, abundance, Importance Value Index (IVI), species diversity, dominance concentration, species richness, equitability, and beta diversity were analyzed through basic arithmetic calculations for comparing different agroforestry systems.In each site, 20 quadrats of 10m x 10m were established to observe trees and shrubs. The vegetative structure of trees and shrubs in each site was evaluated for frequency, density, and abundance using expressions formulated by Curtis and McIntosh in 1950. The dominant tree species observed in both study sites was Acacia nilotica. Kashari site exhibited superior values in terms of Concentration of Dominance (Simpson Index), Equitability, Beta diversity, and Species diversity. However, Korihar site showed higher species richness.

Key words:Floristic, Agroforestry, Herbaceous, Geographical location

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Introduction:

India boasts a rich history of agroforestry (AF) systems, with numerous indigenous practices evolving over time to cater to local needs and site-specific conditions. These systems encompass various forms, including trees integrated into farmlands, community forestry initiatives, and diverse local forest management and ethno forestry practices (Gairola et al., 2008). Throughout India, the tradition of cultivating scattered trees on agricultural plots has persisted for centuries, largely unchanged. These trees serve multiple purposes, providing shade, fodder, fuelwood, fruits, vegetables, and medicinal resources (Bijalwan et al., 2011; Dey et al., 2022).

Understanding the structure, composition, and phyto diversity of existing sites requires a close examination of their land use patterns (Umrao et al., 2017). Farmers have increasingly embraced the practice of integrating trees into agricultural landscapes, driven by both economic incentives and social advantages. However, there is a growing recognition of the need for integrated approaches, drawing upon expertise from agricultural and forestry domains, to optimize crop suitability and location-based considerations (Ranjan et al., 2016; Chaurasia et al., 2022).

Given the challenges posed by climate change and environmental shifts, there is a pressing need for innovative land-use options that enhance livelihood security and resilience (Pathak et al., 2016; Mishra et al., 2022). Such approaches should be tailored to local contexts while promoting sustainability and adaptability in the face of evolving environmental conditions.

The community structure, composition, and vegetative function stand out as pivotal ecological attributes of forests, showcasing fluctuations in response to both environmental factors and human activities (Gairola et al., 2008; Timilsina et al., 2007). Species diversity, a cornerstone of natural communities, plays a significant role in shaping ecosystems (Chaurasia et al., 2020). The variations observed in vegetation structure, richness, diversity, and distribution are closely tied to factors such as geographical location and agricultural practices (Criddle et al., 2003).

In Central and Eastern Uttar Pradesh, agroforestry systems have firmly taken root. Multiple cropping, a form of natural resource management integrating trees, pasture, and cropland, aims to maximize social, economic, and environmental benefits (Rawat et al., 2009). This traditional practice involves planting and harvesting various products, including wood, fruits, roots, leaves, fuel, and fodder alongside agricultural crops. However, contemporary agroforestry techniques often appear underdeveloped and exploitative, with inadequate protection and management of trees by farmers. Consequently, there exists significant potential for enhancing traditional agroforestry systems to fully unleash their production capacity.

Moreover, greater agrobiodiversity not only fosters long-term stability in carbon storage amid fluctuating environments but also enhances biomass production potential (Henry et al., 2009; Kumar, 2006). The primary objective of this study is to elucidate the structural attributes of density, frequency, diversity, equitability, and species richness within existing agroforestry systems in Fatehpur and Allahabad districts of Uttar Pradesh. Such investigations aid in identifying the dominant communities of timber trees, horticultural trees, and shrub species, thereby pinpointing areas conducive to the protection and promotion of these plants.

MATERIAL AND METHODS:

The research endeavor was conducted within the eastern region of Uttar Pradesh, specifically in the vicinity of Allahabad. Two distinct village sites, Kashari (site-I) and Korihar (site-II), were carefully chosen within Allahabad district for the study. Situated on the eastern bank of the Ganga river, these sites lie approximately 20 kilometers and 35 kilometers away from the bustling city of Allahabad, precisely positioned at 81°50' E longitude and 25°27' N latitude.

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Map.1 - Map of the study areas

Floristic -Diversity: The investigation into floristic diversity employed a random sampling methodology, wherein 20 quadrats of 10m x 10m size and 5m x 5m size were systematically laid out within each site for the examination of trees and shrubs, respectively. Various parameters including density, frequency, abundance, Importance Value Index (IVI), species diversity, concentration of dominance, species richness, equitability, and beta diversity were meticulously scrutinized through straightforward arithmetic calculations to facilitate the comparison of different agroforestry systems.Quantitative assessments of vegetation were conducted utilizing the quadrat method. The vegetative structure of trees and shrubs across the two sites was assessed for frequency, density, and abundance, applying established expressions formulated by Curtis and McIntosh in 1950. The floristic diversity study entailed the deployment of random sampling techniques, with 20 quadrats measuring 10m x 10m laid out in each site for the observation of trees and shrubs. Herbaceous species were not included in the floristic diversity assessment.Basal area calculations were performed to gauge the dominance and distribution of trees and shrubs. For trees, basal area was computed as the cross-sectional area of the stem at Diameter Breast Height (DBH) of 1.37 meters. Similarly, for shrubs, basal area was determined as the cross-sectional area of the main stem measured 15 centimeters above ground level, utilizing the formula: Basal Area = π (d^2/4), where 'd' represents the diameter of the tree or shrub.

$$\text{Frequency} = \frac{\text{Number of sampling units in which species occurred}}{\text{Total number of sampling unit studies}} \times 100$$

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$$\text{Density} = \frac{\text{Total number of individual of species}}{\text{Total number of quadrat studied}}$$

$$\text{Abundance} = \frac{\text{Total number of individual of the species in all sampling units}}{\text{Number of sampling unit in which the species occurred}}$$

$$\text{Basal area per tree} = \frac{\text{Total basal area of trees}}{\text{Number of trees}}$$

Relative Basal Area: The relative density, relative frequency, relative basal areas were calculated using following formula.

$$\text{Relative density} = \frac{\text{Density of individual of species}}{\text{Total density of all species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of the individual species}}{\text{Total frequency of all the species}} \times 100$$

$$\text{Relative basal area} = \frac{\text{Basal area of the individual of species}}{\text{Total basal area of all the species}} \times 100$$

Importance Value Index: The importance value index (IVI), which is an integrated measure of the relative frequency, relative density and relative basal area/dominance, was calculated for each tree species given by Curtis, 1959.

Importance Value Index (IVI) = RD+RF+RBA

The number of trees falling in the sample unit was counted and classified as per their diameter and height characteristics. The Species diversity (Shannon index), concentration of dominance (Simpson index) and other useful parameters for comparison of different types of existing agroforestry systems were calculated (Shannon and Weaver, 1963 and Simpson, 1949).

Tree diversity analysis:

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Tree diversity in all four sites of agroforestry systems (trees and shrubs) were calculated by the following diversity indices. [42]

(a) **Species Diversity Index.** It was calculated by the formula given byMargalef, 1958.

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$$H = -\sum [(ni/N) \log (ni/N)]$$

Where ni was the total number of individuals of species N was the total number of individuals of all the species on that site.

(b) **Concentration of dominance**was measured by the formula of Simpson Index developed by Simpson, 1949.

$$Cd = -\sum\left[\left(\frac{n_1}{N}\right)^2 + \left(\frac{n_2}{N}\right)^2 + ---\left(\frac{n_n}{N}\right)^2\right]$$

Where N was the total number of individuals of species ni was the total number of individuals of all the species on that site.

(c) **Equitability(e)** was calculated as suggested by Pielou (1975)as

e = H/ In s

Where H is the Shannon – Wiener Index and s = total number of species

(d) **Species richness** was calculated by the following equation of Margalef (1958)

d = s- 1/In N

Where s = number of species, and N =number of individuals of all species

(e) **Beta diversity** was calculated as outlined by Whittaker, 1977

bd = Sc / s

Where Sc = total number of species in all sites and average species per site.

RESULTS AND DISCUSSION

Floristic-diversity analysis and distribution patterns of tree species:

The distribution patterns and species composition of existing agroforestry systems viz. agrisilvicultural and agrihorticultural system commonly practiced in Allahabadwas studied. [42]

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Floristic diversity at Site –I (Kashari) of Allahabad district: The results of florisitic-diversityat site-I are presented in table 1 and graphically illustrated in figure 1. It is evident from the data that among tree species available in site –I timber and fuelwood, horticultural and shrubs species were 18, 8 and 4, respectively. The dominant and co-dominant species were *Acacia nilotica* and *Azadirachtaindica* showed IVI values of 24.54 and 24.09, respectively. The highest (70 trees ha^{-1}) value of density was recorded for *Acacia nilotica* in timber and fuel wood tree species followed by *Azadirachtaindica* (65 trees ha^{-1}). The highest tree density was recorded for*Emblicaofficinalis* (70 trees ha^{-1}) among horticultural tree species followed by *Mangiferaindica* (35 trees/ha). Total basal cover for tree was recorded higher for *Ficusreligiosa (*5.144 m^2/ha) followed by *Madhucalatifolia (*5.1094 m^2/ha). Among horticulture and shrubs species, the dominant and co-dominant species were *Emblicaofficinalis* and *Mangiferaindica* with IVI values of 18.89 and 16.207, respectively.

Table 1: Floristic- diversity of site-I (Kashari)of Allahabad district

Timber and fuelwood trees										
Name of the species	**Density (100m^2)**	**Frequency**	**Abundance**	**BA (cm^2)/ 100m^2**	**Relative Density**	**Relative Frequency**	**Relative Basal Area(RBA)**	**IVI**	**B.A. M^2/ha.**
*Acacia nilotica*L.Willd.ex del.	0.70	55	1.27	393.56	8.04598	8.02920	8.46728	24.54246	3.9356
Aegle marmelos(L.)Corr.	0.25	20	1.25	151.81	2.87356	2.91971	3.26609	9.05936	1.5181
*Artocarpusheterophylus*L.	0.25	15	1.67	146.61	2.87356	2.18978	3.15428	8.21762	1.4661
*Azadirachtaindica*L.	0.65	60	1.08	365.45	7.47126	8.75912	7.86248	24.09287	3.6545
Dalbergiasissoo Roxb.	0.20	15	1.33	138.80	2.29885	2.18978	2.98625	7.47488	1.388
Eucalyptus teretiocornis Sm.	0.30	25	1.20	143.23	3.44828	3.64964	3.08144	10.17935	1.4323
Ficusbenghalensis L.	0.25	20	1.25	373.92	2.87356	2.91971	8.04468	13.83795	3.7392
*Ficusglomerata*L.	0.30	25	1.20	179.69	3.44828	3.64964	3.86592	10.96383	1.7969
Ficusreligiosa L.	0.35	20	1.75	514.40	4.02299	2.91971	11.06723	18.00992	5.144
Limoniaacidessima L.	0.25	25	1.00	162.47	2.87356	3.64964	3.49556	10.01875	1.6247

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Madhucalatifolia Macb.	0.40	30	1.33	510.94	4.59770	4.37956	10.99258	19.96984	5.1094
Pongamiapinnata L.	0.20	10	2.00	187.04	2.29885	1.45985	4.02408	7.78279	1.8704
Populus deltoids Bartrx.ex.Marsh	0.20	15	1.33	87.226	2.29885	2.18978	1.87663	6.36526	0.8723
Prosopisjuliflora (sw) DC.	0.25	15	1.67	34.851	2.87356	2.18978	0.74980	5.81315	0.3485
Syzygiumcumini(L.)Skeel	0.20	10	2.00	187.26	2.29885	1.45985	4.02875	7.78745	1.8726
Tamarindusindica L.	0.20	15	1.33	224.53	2.29885	2.18978	4.83072	9.31935	2.2453
*Tectonagrandis*Linn.f.	0.60	50	1.20	194.27	6.89655	7.29927	4.17967	18.37549	1.9427
*Zizyphusmaritiana*Lam	0.25	25	1.00	129.84	2.87356	3.64964	2.79346	9.31666	1.2984
Horticultural trees										
Carica papaya L.	0.20	10	2.00	12.031	2.29885	1.45985	0.25885	4.01755	0.1203
*Carissa corandus*L.	0.30	25	1.20	9.9589	3.44828	3.64964	0.21426	7.31217	0.0996
Citrus lemon(L)Burm.f	0.30	30	1.00	10.424	3.44828	4.37956	0.22427	8.05210	0.1042
CordiamyxaRoxb.	0.15	10	1.50	3.5652	1.72414	1.45985	0.07670	3.26070	0.0357
*Emblicaofficinalis*Gaertn	0.70	60	1.17	96.851	8.04598	8.75912	2.08372	18.88882	0.9685
Mangiferaindica L.	0.35	30	1.17	362.76	4.02299	4.37956	7.80474	16.20729	3.6276
*Musa paradesiaca*L.	0.15	10	1.50	2.3339	1.72414	1.45985	0.05021	3.23420	0.0233
*Psidiumguajava*L.	0.15	10	1.50	21.959	1.72414	1.45985	0.47245	3.65644	0.2196
Shrubs species										
*Bougainvillaglabra*L.	0.20	15	1.33	0.8458	2.29885	2.18978	0.01820	4.50683	0.0085
Jatrphacurcas L.	0.15	10	1.50	0.6453	1.72414	1.45985	0.01388	3.19788	0.0065
Ricinuscommunis	0.15	15	1.00	0.7074	1.72414	2.18978	0.01522	3.92914	0.0071

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L.									
Ziziphuszizyphus L.	0.10	10	1.00	0.0332	1.14943	1.45985	0.00071	2.60999	0.0003
Total	**8.70**	**685**	**40.74**	**4648**	**100.0**	**100.0**	**100.0**	**300.0**	**46.48**

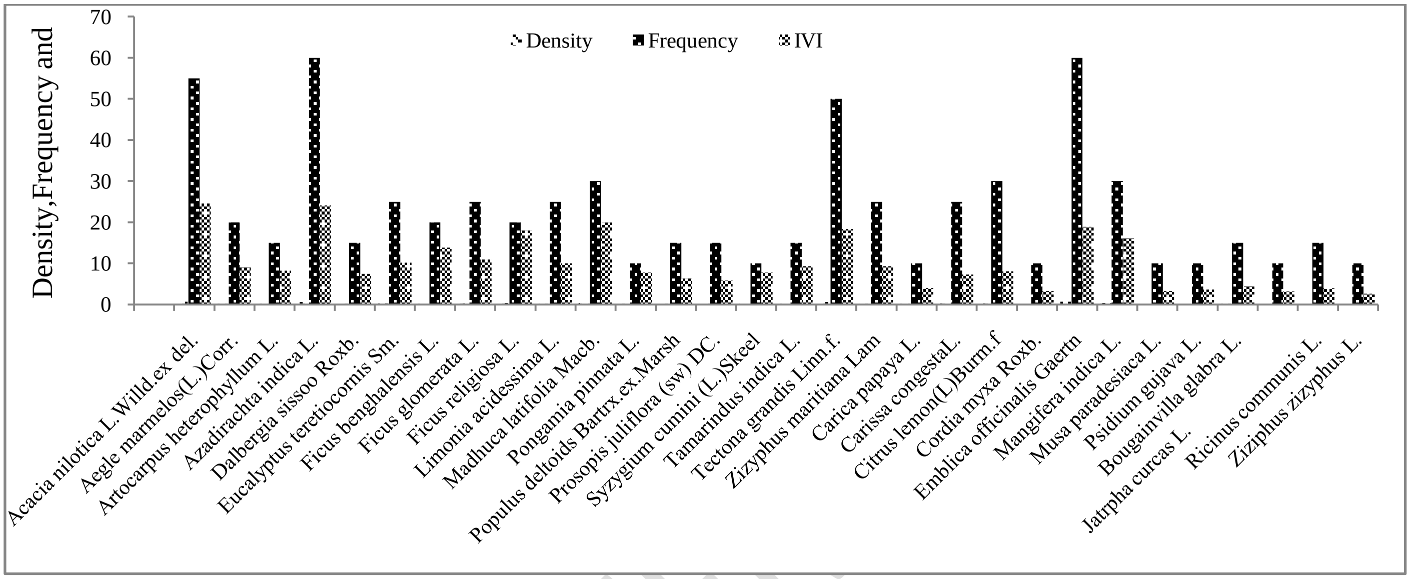

Fig .1:Floristic diversity of site-I (Kashari)of Allahabad district

2.Floristic- diversity analysis at site –II (Korihar) of Allahabad district:

The findings pertaining to the floristic diversity at Site-I are elucidated in Table 1 and visually depicted in Figure 1. Analysis of the data reveals that among the tree species observed at Site-I, there were 18 species classified as timber and fuelwood, 8 categorized as horticultural, and 4 designated as shrubs. Notably, the dominant and co-dominant species, Acacia nilotica and Azadirachtaindica, exhibited noteworthy Importance Value Index (IVI) values of 24.54 and 24.09, respectively, underscoring their ecological significance.

In terms of density, Acacia nilotica stood out with the highest recorded value of 70 trees per hectare among timber and fuelwood species, closely followed by Azadirachtaindica at 65 trees per hectare. Among horticultural species, Emblicaofficinalis boasted the highest tree density at 70 trees per hectare, followed by Mangiferaindica at 35 trees per hectare. The cumulative basal cover for trees was found to be highest for Ficusreligiosa at 5.144 square meters per hectare, followed closely by Madhucalatifolia at 5.1094 square meters per hectare.Within the categories of horticulture and shrubs, Emblicaofficinalis emerged as the dominant species, exhibiting an IVI value of 18.89, followed by Mangiferaindica with an IVI value of 16.207, highlighting their prominence within the ecosystem.

Table 2 Floristic -diversity of site-II (Korihar) of Allahabad district

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Name of the species	**Density (100m^2)**	**Frequen-cy**	**Abunda-nce**	**BA (cm^2)/ 100m^2**	**Relative Density**	**Relative Frequency**	**Relative Basal Area(RBA)**	**IVI**	**B.A. M^2/ha.**
Timber and fuelwood trees									
*Acacia nilotica*L.Willd.ex del.	0.60	50	1.20	281.36	7.69231	8.19672	7.19095	23.0799	2.8136
Aegle marmelos(L.)Corr.	0.25	20	1.25	137.94	3.20513	3.27869	3.52549	10.0093	1.3794
Albiziaprocera L.	0.15	10	1.50	62.999	1.92308	1.63934	1.61011	5.17253	0.63
*Artocarpusheterophylus*L.	0.25	20	1.25	127.23	3.20513	3.27869	3.25165	9.73547	1.2723
*Azadirachtaindica*L.	0.50	45	1.11	363.06	6.41026	7.37705	9.27909	23.0663	3.6306
DalbergiasissooRoxb.	0.25	15	1.67	219.78	3.20513	2.45902	5.61721	11.2813	2.1978
Eucalyptus teretiocornis Sm.	0.25	20	1.25	123.95	3.20513	3.27869	3.16787	9.65169	1.2395
Ficusbenghalensis L.	0.20	20	1.00	281.84	2.56410	3.27869	7.20319	13.0459	2.8184
*Ficusglomerata*L.	0.30	25	1.20	189.05	3.84615	4.09836	4.83165	12.7761	1.8905
Ficusreligiosa L.	0.20	20	1.00	268.56	2.56410	3.27869	6.86371	12.7065	2.6856
*Madhucalatifolia*Macb.	0.40	30	1.33	453.11	5.12821	4.91803	11.58055	21.6267	4.5311
Pithecellobiumdulce (Roxb.)Benth.	0.20	15	1.33	152.19	2.56410	2.45902	3.88953	8.91265	1.5219
Pongamiapinnata L.	0.30	25	1.20	129.73	3.84615	4.09836	3.31562	11.2601	1.2973
Populus deltoids Bartrx.ex.Marsh	0.20	10	2.00	41.854	2.56410	1.63934	1.06969	5.27314	0.4185
Prosopisjuliflora (sw) DC.	0.30	15	2.00	41.821	3.84615	2.45902	1.06885	7.37402	0.4182
Syzygiumcumini(L.)Skeel	0.20	10	2.00	143.61	2.56410	1.63934	3.67024	7.87369	1.4361
*Tectonagrandis*Linn.f.	0.65	55	1.18	230.62	8.33333	9.01639	5.89412	23.2438	2.3062
*Zizyphusmaritiana*Lam	0.35	25	1.40	102.33	4.48718	4.09836	2.61529	11.200	1.0233
Horticultural trees									
Carica papaya L.	0.20	10	2.00	12.031	2.56410	1.63934	0.30749	4.51094	0.1203
*Carissa corandus*L.	0.30	25	1.20	9.9589	3.84615	4.09836	0.25453	8.19904	0.0996
*Emblicaofficinalis*Gaertn	0.60	50	1.20	83.015	7.69231	8.19672	2.12169	18.0107	0.8302
*Mangiferaindica*L.	0.30	20	1.50	427.76	3.84615	3.27869	10.93273	18.0575	4.2776
*Musa paradesiaca*L.	0.15	10	1.50	2.3339	1.92308	1.63934	0.05965	3.62207	0.0233

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*Psidiumguajava*L.	0.15	10	1.50	21.321	1.92308	1.63934	0.54491	4.10733	0.2132
Shrubs species									
*Bougainvillaglabra*L.	0.20	15	1.33	0.8458	2.56410	2.45902	0.02162	5.04474	0.0085
Jatrphacurcas L.	0.15	15	1.00	3.7623	1.92308	2.45902	0.09616	4.47825	0.0376
Ricinuscommunis L.	0.15	15	1.00	0.7074	1.92308	2.45902	0.01808	4.40017	0.0071
*Ziziphuszizyphus*L.	0.05	10	0.50	0.0166	0.64103	1.63934	0.00042	2.28079	0.0002
Total	**7.80**	**610**	**37.6**	**3912.8**	**100.0**	**100.0**	**100.0**	**300.0**	**39.128**

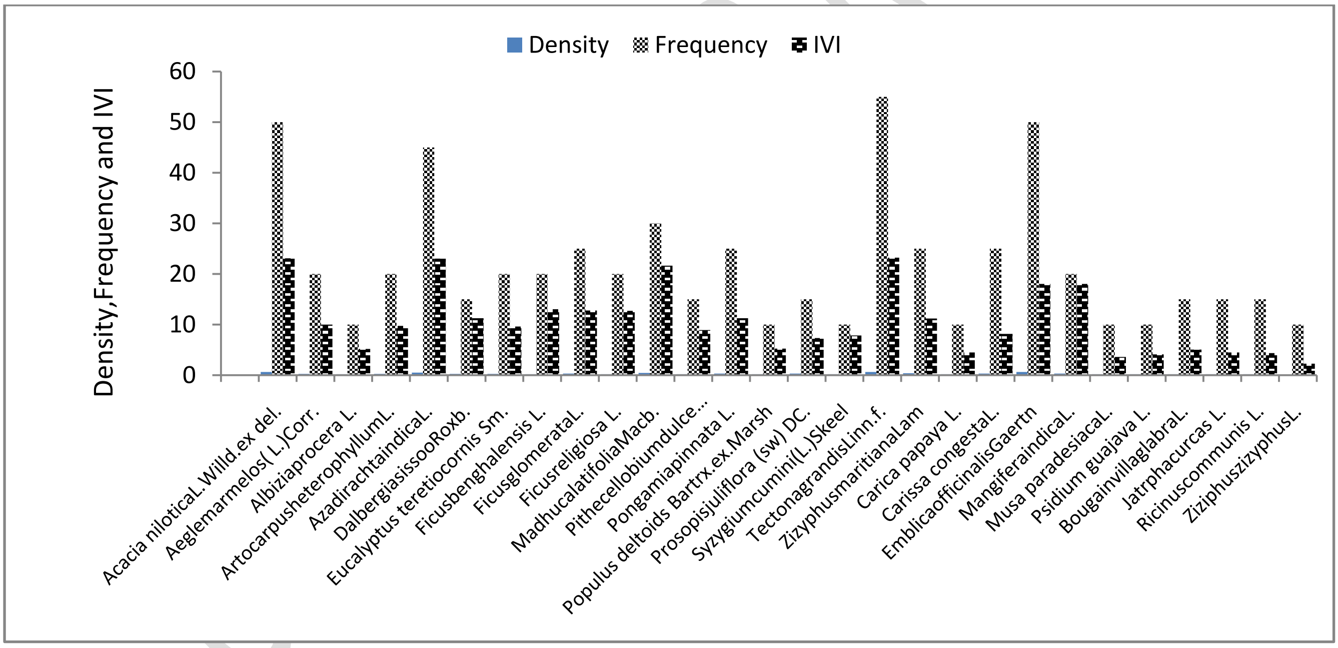

Fig2 Floristic diversity of site-II(Korihar)of Allahabaddistrict

3. Diversity index analysis: The diversity index analysis of vegetation from both sites in the district of Allahabad is detailed in Table 3. The index of dominance, represented by the Simpson index, exhibited higher values in the agrisilviculture system at Site-II (0.038), followed closely by Site-I (0.035). Species diversity (sd) peaked at Site-II (0.999), whereas in the agrihorticultural system, the highest species diversity was recorded at Site-I (0.330), with the lowest observed at Site-II (0.308).

Equitability (e) of trees showed maximal values (0.055) in the agrisilviculture system at Site-I, while the minimum was recorded at Site-II (0.038) in the agrihorticulture system. The highest species richness was found in the agrisilviculture system at Site-II (0.153), closely followed by Site-I (0.152) in the agrihorticulture system, whereas the lowest was observed in the agrisilviculture system at Site-I (0.146).

Beta diversity reached its peak in the agrihorticulture system at Site-II (5.167) and was lowest at Site-I (3.875) in the same system. These diversity index results are corroborated by the findings of Knight (1975). Notably, the modified Simpson's Index Value yielded almost similar observations as reported by Jose et al. (1994). Basha (1987) also reported a Simpson's index of diversity of 0.94 for evergreen forests of Silent Valley.

The Shannon-Wiener Index Value (H') indicated that the diversity closely resembled that of a tropical forest, registering at 5.45. Typically, H' values in tropical rainforests range from 5.06 in young stands to 5.4 in older stands (Knight, 1975).

Table 3: Diversity Index of study sites-I and II of Allahabad districts:

AF system	Species – Diversity Index (Shannon Index)		Simpson Index(Concent-ration of Dominance)		Species Richness		Equitability		Beta Diversity	
	Trees	**Shrubs**	**Trees**	**Shrubs**	**Trees**	**Shrubs**	**Trees**	**Shrubs**	**Trees**	**Shrubs**
AS/S_I	0.970	0.060	0.035	0.0002	0.146	0.250	0.053	0.020	3.944	4.667
AS/S_{II}	0.999	0.064	0.038	0.0002	0.153	0.272	0.055	0.021	3.944	4.667
AH/S_I	0.308	0.027	0.007	0.0002	0.152	0000	0.038	0.027	3.875	6.000
AH/S_{II}	0.262	0.028	0.008	0.0002	0.147	0000	0.043	0.028	5.167	6.000

CONCLUSIONS:

The findings from the present study lead to the conclusion that Acacia nilotica emerged as the most dominant tree species across both study sites. However, when considering various diversity metrics, it becomes evident that each site possesses distinct strengths.In terms of the Concentration of Dominance, represented by the Simpson Index, as well as Equitability, Beta diversity, and Species diversity, the Kashari site demonstrated superiority. These metrics suggest a more balanced and diverse ecosystem at the Kashari site compared to the Korihar site.On the other hand, while Kashari excelled in several diversity indices, Korihar stood out for its higher species richness. This indicates a higher variety of species present at the Korihar site, although it may not possess the same level of balance and evenness as observed in Kashari.Overall, these conclusions highlight the importance of considering multiple aspects of biodiversity when assessing the ecological health and richness of an area. Each site may have its unique strengths and contributions to overall biodiversity, emphasizing the need for comprehensive conservation and management strategies tailored to specific ecological contexts.

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