Original Research Article

Species Diversity and Standing Stock of Homestead Forestry in Singrauli District of Madhya Pradesh, India

Abstract

Loss of biodiversity is one of the triple planetary crises that needs to be addressed with urgency to shape a sustainable habitat for all life forms. This paper investigatesthe diversity, composition and standing stock in rural homesteads of Singrauli District, MP, India. A multi-stage random sampling was used to select villages (16) and households (128) for the field survey. Data on species composition and standing stock were collected using interview schedules and homestead inventories. Data were analysed through descriptive statistics, mensuration formulas, and diversity indices. Results indicated that about 153 species of plants belonging to 55 families and 122 genera of flora were raised other than conventional agricultural crops in homesteads.Among these, 92 tree, 26 shrub, 25 herbaceous, and 10 climber species were identified.On average, households practiced homestead forestry in an area of 0.25 ha, with 47 individuals of 15 species. The average height, diameter, basal area, and standing stock of trees in the homesteads were recorded as 34.50 cm, 12.01 m, 934.82 cm^2, and 15.18 m^3,respectively. The Shannon-Wiener diversity index of 3.57 and Simpson's index of 0.05 implied high floristic diversity, and the Shannon Equitability index of 0.70 indicated a considerably even population of plant species. The Importance Value Index (IVI) indicated that*Mangifera indica*(27.78) and*Madhuca longifolia* (18.96) were found to be the dominant species in the sample homesteads owing to their multi-faceted uses.The findings specified that homestead forestry can be a viable strategy to conserve biodiversity, improve ecosystem services, expand the green cover, and secure livelihoods.

Keywords: Homestead forestry, species diversity, standing stock, IVI, Singrauli, M.P., India.

1. Introduction

Homestead forestry is an intimate association of multipurpose trees and shrubs with annual and perennial crops and, invariably, livestock within the compounds of individual houses, with the whole crop tree animal unit being managed by family labour (Fernandes and Nair, 1986). It consists of multi-stories of timber, fruits, fuelwood, fodder, and other multipurpose tree (MPT) species as a source of diverse livelihood income and sustenance (Baul *et al.*, 2021). Nair and Sreedharan (1986) defined a homestead as "an operational farm unit in which a number of crops (including tree crops) are grown with livestock, poultry, and/or fish production mainly for the purpose of satisfying the farmer's basicneeds". Jacob (1997) proposed a more comprehensive definition of the homestead as "a functional/operative and self-sustaining farm unit that consists of a conglomeration of crops and multipurpose trees, planted arbitrarily, with or without animals/poultry/apiculture, owned and

primarily managed by the dwelling farm family, with the objectives of satisfying basic family needs (food, fuel, and timber) and producing marketable surplus for the purchase of non-producible items".

Homestead forestry is common in all ecological regions in the tropics and subtropics, especially in humid lowlands with high population density, being referred to by different names in different places such as *'Pekarangan'* in Java, Indonesia, *'Homegarden'* in the South Pacific Islands and Philippines, *'Kandayan'* in Sri Lanka, *'Compound Garden'* in Kerala, *'Compound Farm'* in south-east Nigeria, *'Chagga homegarden'* in Northern Tanzania, *'Ka/Fuyo garden'* in Burkina Fasso, and *'Huerlos Familiaries'* in Mexico (Nair, 1993).Homestead forests are also referred to as *"Biodiversity Island"* of a country due to their species richness or diversity (Alam and Furukawa, 2010). The tree species diversity in different homestead forests varies based on the agro-ecological zone, size of land, and function of that homestead forest (Mohri*etal*., 2013; Gbedomon*et al*., 2017).The average size of a homestead forest is usually much less than a hectare. In India, every homestead has around 0.2 to 0.5 ha of land for personal production (Ali, 2005). Spatial constraints are the major reason for reduced diversity in homestead forests.There is a substantial decline in the dependence on homestead forests with lower species diversity, whereas homestead forests with larger species diversity are the results of a gradual shift from single-species-dominated land use to multispecies systems (Unnithan *et al*., 2017). Various species of fruits, timber, crops, vegetables, shrubs, herbs, and medicinal plants are found in various locations of homestead forests (Rahman *et al*., 2017).

Madhya Pradesh falls in the subtropical zone and experiences a tropical monsoon climate, which is favourable for practicing homestead forestry. The structure of a homestead forest can resemble that of tropical forests, with canopy strata formation, high plant density, and biomass and carbon storage (Lowe *et al*., 2022).The most common trees that can be found in homestead forestry of Madhya Pradesh are babul, neem, shisham, teak, bamboo, palash, mahua, jamun, aonla, mango, guava, subabul, kahmer, etc. for the purpose of food, fuelwood, and timber (Bijalwan*et al*., 2019). Homestead forestry can be used as an efficient tool for biodiversity conservation.Yismaw and Tadesse (2018) found out that not only natural ecosystems but also human-managed systems can be used for conservation and sustainable utilization of plant diversity, which in turn can enhance other biological diversity. The rich biodiversity of homesteads increases soil organic carbon, enhances nutrient cycling, improves biomass production, and secures long-term carbon storage and stability (Brown et al., 2018).Keeping this in view, the present investigation was carried out to assess the species diversity and standing stock of homestead forestry in Singrauli district of Madhya Pradesh.

2. Materials and Methods

2.1. Study area

The present investigation was carried out in Singrauli district of Madhya Pradesh (Figure 1). The district is situated on the north-eastern part of the state, extending between latitudes 23°49' and 24°42' North and longitudes 81°18' and 82°48' East. It has 3 blocks, or vidhan sabha, namely Deosar, Chitrangi, and Baidhan. It lies in the warm tropical monsoon belt of India and experiences hot

summers and chilly winters.The district experiences an average temperature of 31.9°C – 45.3°C in summer and 5.4°C – 21.6°C in winter. The average annual rainfall in the district is 720.2 mm. The soils of the district vary from medium to light in texture, and the fertility of the soil is poor in general.The highest topographic elevation in the district is 609 m above sea level in Chitrangi lock. The district is spread across a total geographic area of 5675 km^2 or 3,99,837 hectares, out of which the forest area is 11,841 hectares (i.e., 2.96% of the total geographical area) and the cultivated area is 2,25,946 hectares with 39,456 hectares of cultivable barren lands (Census of India, 2011).

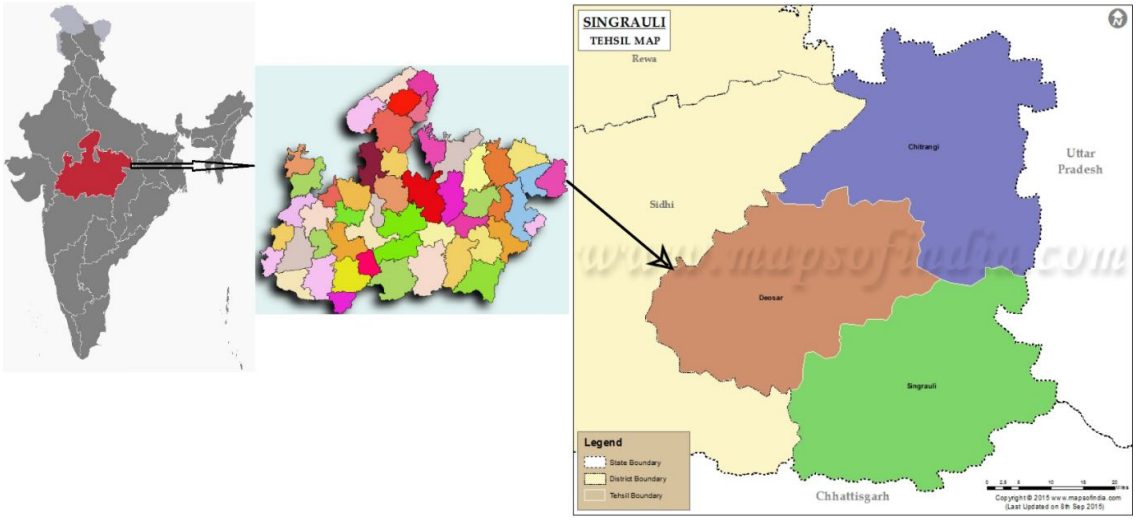

Figure 1: Location map of study area

2.2. Sampling method

Multistage Random Sampling Technique (Ray & Mondol, 2004) was employed to select villages and the households. The first stage involves random sampling for the selection of sixteen sample villages (Deeghar Khurd, Rakhsahat, Redi, Tikuritola, Machi Kalan, Gawardehi, Birchhi, Sanda, Tal, Jhurhanar, Dudhiyatola, Kadopani, Sigahi, Ladbai, Padari Khairwari Tola, and Bhunda) from all three blocks: Deosar (5 villages), Chitrangi (6 villages), and Baidhan (5 villages).In the second stage, a total of 128 households are selected for field studies from those sixteen sample villages. The sampling intensity was kept at 20% for selection of villages from all three blocks and 10% for selection of households from those 16 villages.

2.3. Data collection

The data has been collected from both secondary sources and primary field surveys. Secondary sources included literature from various journals, research reports, forest department records, village records, the internet, previous research, annual reports, and other related documents from different governmental and non-governmental agencies. Primary data has been collected through personal interviews of the respondents through a well-structured, pre-tested interview schedule (Kumar, 2012)

and the homestead inventories.The data regarding the diversity, composition, and standing stock in homesteads collected were Area of homestead, number of trees, tree height, DBH (Diameter at Breast Height), collar diameter, form factor, volume, density, species occurrence, frequency, relative frequency, relative density, total basal area, and relative dominance (or relative basal area) were used to calculate IVI and Diversity indices vis-à-vis the Shannon-Wiener diversity index (Shannon & Wiener, 1963) and Simpson's index (Simpson, 1949).

2.4. Data analysis

The data collected from field surveys was organized and evaluated in MS Excel considering the objectives of this research. Simple descriptive statistics, mensuration formulas, and diversity indices were used to analyze the data. The form factor in the present study has been kept at 0.50 (Subedi *et al*., 2021).

3. Results and Discussion

3.1. Species diversity

The investigation documented 153 species in homestead forestry belonging to 122 genera under 55 families. Among 153 species found in homesteads, 92 were tree species, 26 were shrubs, 25 were herbaceous, and 10 of them were climber species. The family Fabaceae had the highest representation of 28 species followed by Poaceae (9), Apocynaceae and Combretaceae (7 each), Moraceae and Rutaceae (6 each), Solanaceae (5), Euphorbiaceae (4), Lamiaceae (4), Lauraceae (4), Malvaceae (4), Myrtaceae (4), Anacardiaceae (3), Arecaceae (3), Asparagaceae (3), Asteraceae (3), Burseraceae (3), Lythraceae (3), Annonaceae (2), Celastraceae (2), Meliaceae (2), Musaceae (2), Rhamnaceae (2), Rubiaceae (2), Sapindaceae (2), Sapotaceae (2), Verbenaceae (2), Phyllanthaceae (2), and Acanthaceae, Amaranthaceae, Apiaceae, Araceae, Bixaceae, Cactaceae, Caricaceae, Convolvulaceae, Dioscoreaceae, Dipterocarpaceae, Ebenaceae, Hypoxidaceae, Liliaceae, Loganiaceae, Magnoliaceae, Menispermaceae, Moringaceae, Oleaceae, Piperaceae, Plumbaginaceae, Proteaceae, Putranjivaceae, Rosaceae, Santalaceae, Simaroubaceae, Ulmaceae and Vitaceae with 1 species each. The genera *Acacia*, *Bambusa*, and *Terminalia* revealed the highest representation of 5 species each, followed by *Citrus* and *Ficus* (3 species each); *Albizia*, *Anogeissus*, *Artocarpus*, *Bauhinia*, *Butea*, *Carissa*, *Cassia*, *Cestrum*, *Cinnamomum*, *Cymbopogan*, *Dalbergia*, *Eucalyptus*, *Musa*, *Tagetes*, and *Ziziphus* (2 species each); and the remaining 102 genera with 1 species each.The analysis revealed that the homestead forests in the district are highly diverse. The Shannon-Weiner Diversity Index (H) was 3.57, indicating a very diverse homestead forest, and the Shannon Equitability Index (E) was 0.71, representing a considerably even population of plant species (Table 1).The Simpson's Index (D) was 0.05, and Simpson's Dominance Index (1/D) came out as 19.14. The survey of sample homesteads indicated that people intend to plant different species of plants for both materialistic and nonmaterialistic benefits (Figure 2).Different species of fruits were planted for varied tastes and good health. Various species were planted for their medicinal use and use as condiments and spices.

Gardening and beautification of homestead compounds were one of the major reasons for the presence of a large number of species.

Table 1: Diversity indices of forest plants in sample homesteads (N = 128)

Attributes	Value
Shannon-Weiner Diversity Index (H)	3.57
Shannon Equitability Index (E)	0.71
Simpson's Index (D)	0.05
Simpson's Dominance Index (1/D)	19.14

(a) Homestead in Singrauli (b) Diversity in homestead

Figure 2: Homestead Forestry in thestudy area

3.2. Importance Value Indices (IVI) of homestead forest plants

The relative frequency, relative density, relative basal area, and importance value index (IVI) of the plant species across the canopy layers in the homestead forestry are given in Table 2. The emergent canopy showed the highest IVI of 107.14, followed by herbs (70.69), the main canopy (46.85), the understory (39.32), and lastly, shrubs (35.99). *Mangifera indica*is the dominant tree species in the region and exhibited the highest IVI of 27.78, followed by*Madhucalongifolia*(18.96) in second place.Mangifera indica also showed the highest number of occurrences in 109 homesteads. For the total number of tree individuals, *Dendrocalamusstrictus* had the highest number of 322 (each culm was counted as an individual tree), followed by*Mangiferaindica*(263).Total six species of bamboo were recorded across the sample homesteads, which were *Bambusatulda*, *Bambusabalcooa*, *Bambusanutans*, *Bambusabamboos*, *Bambusavulgaris*, and *Dendrocalamusstrictus*. The restructured National Bamboo Mission (NBM), 2018 is the reason for the presence of different bamboo species in the district. In Madhya Pradesh, the National Bamboo Mission is operated through the Tropical Forest Research Institute (TFRI) in Jabalpur.TFRI Jabalpur offered various training events on bamboo nurseries and management, calling farmers from various corners of the state and also providing them with saplings of different bamboo species. The total basal area was highest for *Mangiferaindica* (39.07 m^2; relative basal area (RBA) = 17.85%), followed by *Madhucalongifolia* (34.65 m^2; RBA = 15.83%). The highest standing volume of timber was for *Mangiferaindica* (389.15 m^3) followed by *Madhucalongifolia* (329.68 m^3).

Table 2: Importance value index (IVI) of the plant species across the canopy layers in the homestead forestry (N= 128)

S. No.	Canopy layer	Relative Frequency	Relative Density	Relative Basal Area	Importance Value Index
1	Emergent layer (≥ 15 m)	22.78	17.23	67.13	107.14
2	Main canopy (10 to 15 m)	12.16	15.16	19.54	46.85
3	Understory (5 to10 m)	18.27	11.48	9.57	39.32
4	Shrubs (1 to 5 m),	18.57	14.37	3.05	35.99
5	Herb (< 1 m)	28.22	41.76	0.71	70.69
	Total	**100**	**100**	**100**	**300**

3.3. Homestead characteristics and standing stock of trees

Homestead characteristics and tree growth statistics for sample homesteads are presented in Table 3.The average size of homestead forests was 0.25 ha, with a range of 0.08 ha to 0.53 ha across the sample homesteads.The total area of all the homestead forests surveyed was 31.84 ha. All the sample households were in strictly village areas with cultivation as a major occupation. People in villages prefer to dwell in and around the fields owned by them, where they have trees planted and practice cultivation.The significant number of sample homesteads did not have physical boundaries embarking the extent of their home compound, which is one of the major reasons for large-sized homestead forests. Across the sample households, homestead forestry can be found practiced in broadly three types of settings.First, homestead forests where people raise plants in front of their houses; gardens or lawns. Second, when plants are raised at the back of the house along with vegetable crops, and lastly, homestead forests where there is no distinguished boundary of the homestead or house are located in the middle of open fields and vegetation is present all around it.

Table 3: Homestead characteristics and growing stock of trees (N = 128)

Attributes	Total	Average ($\bar{x}$ ± SE)	Range
Size of homestead (ha)	31.84	0.25 ± 0.01	0.08 – 0.53
Number of species in a homestead forest	153	15.23 ± 0.41	7 – 38
Homestead forest diversity (no. of species/ha)		67.44 ± 2.44	18 – 187.5
Number of individuals in a homestead forest	5338	41.70 ± 2.128	13 – 144
Density (individuals/ha)		188.04 ± 12.38	43.75 – 862.50
Stock density in homesteads(m^3/ha)		56.01 ± 6.79	1.80 – 160.21
Diameter(cm)		34.50 ± 0.70	3.40 – 153.20
Height(m)		12.01 ± 0.20	0.30 – 32.35
Basal area(cm^2)		934.82 ± 60	9.07 – 18433.48
Standing stock in homesteads (m^3)	1943.61	15.18 ± 2.41	0.32 – 75.57

Note: ha = hectare; $\bar{x}$ = mean; SE = Standard Error

The average number of species found in a homestead forest was 15.23, ranging from 7 to 38 species per homestead. The presence of ornamental (flower), medicinal, and other herbaceous species is the key reason for the large number of species per homestead. A total of 5338 individuals (plants) were recorded across the sample homesteads, with an average of 41.69 ± 2.13 individuals per homestead, which ranged from 13 to 144 individuals per homestead.For bamboos, one culm was regarded as one

individual, and each single plant of small herbaceous species was enumerated separately, which gives the explanation for maximum 144 individuals in a homestead forest. The range for species diversity and plant density was 18–187.5 species/ha and 43.75–862.5 plants/ha in a homestead forest, respectively.The lack of physical demarcation of homestead forest boundaries leading to scattered trees in cultivation fields is one of the main reasons for low density. As explained earlier, counting one bamboo culm as one individual is the major reason for high plant density per homestead.

A total standing stock of 1943.61 m^3 was recorded across all the sample homesteads.The average standing stock per homestead forest was 15.18 m^3 with the minimum and maximum standing stock being 0.32 m^3 and 75.57 m^3 in a homestead forest, respectively.One of the homestead forests in village Sigahi had 49 trees of *Acacia nilotica* in the compound where the respondent's house was located.As a result, a maximum standing stock of 75.57 m^3 came out in that homestead forest.The characteristics of tree holdings in sample homesteads were as follows: height (average = 12.01 ± 0.20 m; minimum = 0.30 m; maximum = 32.35 m), diameter (average = 34.50 ± 0.70 cm; minimum = 3.40 cm; maximum = 153.20 cm), and basal area (average = 934.82 ± 60 cm^2; minimum = 9.07 cm^2; maximum = 18433.48 cm^2). Most of the trees of *Mangiferaindica*, *Madhucalongifolia*, *Terminaliaspp*., *Tamarindusindica*, *Ficusspp*., and some trees of *Syzygiumcumini*, *Aeglemarmelos*, and *Azadirachtaindica* had a large diameter of more than 100 cm. The maximum height of 32.35 m and the maximum diameter of 153.20 cm were recorded for a mature tree of *Mangiferaindica*.

4. Conclusion

The findings led us to conclude that the homesteads in the study area have high species diversity, composition, growing stock, and even populations of species.This homestead forest has diverse life forms of floral species under it and hence can be used as an efficient land use option for maintenance and conservation of biodiversity.Traditionally, the local people use homestead forests for the growing of diverse species for the production of diverse resources for household utilization, leaving no plant part

unused. *Mangifera indica* and *Madhuca longifolia* are the most common woody species in homestead forestry, with a substantial growing stock and density stock.These homestead forests are an enormous source of ecosystem services vis-à-vis provisioning, supporting, regulating, and cultural ecosystem services.

Disclaimer:

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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