



Plant Diversity and Associated Income in Agroforestry Systems of Ayodhya district, Uttar Pradesh

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Abstract: This study was undertaken in the Ayodhya district of Uttar Pradesh to understand the plant species diversity and the associated income in the agroforestry systems. Five agroforestry systems namely, agrisilviculture system, agrisilvihorticulture system, agrihorticulture system, silvipastoral system and aquasilviculture system were found in this district which altogether recorded 95 plant species belonging to 76 genera which consisted of 12 tree species and 83 herb species. The maximum plant species was in agrisilviculture system with 74 plant species (7 tree species and 67 herb species) belonging to 60 genera, followed by agrisilvihorticultural system, aquasilviculture, silvipastoral and agrihorticulture. The Sorenson's Similarity index revealed that all the agroforestry systems had a very low degree of similarity between the vegetation species. The highest average productivity and average income of *Oryza sativa* (Paddy) was in agrisilviculture (40.53 q/ha and Rs. 1,01,325/-) and of *Triticum aestivum* (wheat) was in agrihorticulture and agrisilviculture (27.53 q/ha and Rs. 55,060/-). The agroforestry systems of this region have conserved a high amount of plant diversity. Shifting towards a more diverse plant species cultivation by including indigenous tree species will be recommended for future conservation practices.

Keywords: Agrisilviculture, Agrihorticulture, Aquasilviculture, Agrisilvipastoral, Plant species richness, Silvipastoral

Agroforestry is a land use system which integrates trees on farms to produce diverse products sustainably. It is a complex association of multi-functional and uneven-aged trees and crops (Sanchez, 1995). They are sustainable alternatives to monocultural agriculture system (Tscharntke et al 2010). Agroforestry is a traditional practice in India as in many parts of the world. In Uttar Pradesh, agroforestry systems such as silvipastoral systems, agrisilvicultural systems and agrihorticulture are more commonly practiced. Recently, there has been drastic loss in biodiversity. Plant diversity is reducing at a great speed due to human pressures and climatic factors. As agroforestry is an integrated land use system it can boost plant diversity and reduce habitat loss and fragmentation. The mixing of woody species with agricultural crops increases niche diversification and certain combinations complement each other. Plant diversity forms the basis for productivity and sustainability in any system. There are many reports which suggest that the agroforestry systems conserve biodiversity. Not only that, people depend on agroforestry systems for subsistence, income and other economic gains. The agroforestry systems also provide supplementary income from the tree crops. But in many systems the economic productivity has not been assessed. Therefore, there is a need to quantify the productivity and economic benefits of such agroforestry systems.

Mendez et al (2001) identified 324 plant species in ten different micro-zones of homegarden in Nicaragua. Zimik et

al (2012) carried out a comparative study of homegardens of Assam and Arunachal Pradesh in terms of species diversity and plant utilization pattern. They found that species richness per homegarden varied greatly. A total of 268 species were identified in the studied homegardens with highest percentage of species in herb stratum (37%). Yashmita-Ulman et al (2021) reported a total of 516 plant species. Their study reported that homegardens had the highest species richness, followed by agrisilvicultural systems and the least was in tea gardens. Kaushik and Kumar (2003) worked out the economics of the Khejri (*Prosopis cineraria*)-based agroforestry system and found that higher returns were obtained when any of the fodder crops in sequence was grown in association with Khejri than in monocropping. Maximum net returns and benefit-cost ratio was obtained when pearl millet in kharif followed todia (*Brassica tournefortii*) in rabi under khejri trees. Grain crops, both in kharif and rabi also earned more profit when grown with khejri than alone in arid Haryana, India. Bijalwan et al (2009) reported the annual productivity of all tree species was 3775 kg ha⁻¹yr⁻¹ in northern aspect (site-N) and 3101 kg ha⁻¹yr⁻¹ in southern aspect (site-S) of Garhwal Himalaya. Among the tree species *Grewia optiva* had the maximum productivity in both site-N and site-S, followed by *Melia azedarach*, *Quercus leucotrichophora* and *Celtis australis*. The average biological productivity of agricultural crops in northern aspect was 16% higher as compare to southern aspect under traditional

agrisilviculture system. The northern aspect in traditional agrisilviculture system (Crop+tree) had a highest overall productivity i.e., 24% compared to the southern aspect (21%).

Most of the studies on agroforestry systems in Uttar Pradesh have been on carbon storage potential and crop productivity. But there are no studies in agroforestry systems on plant diversity, composition and associated income. So, this study attempts to assess and compare floristic compositions, structure and associated income in agroforestry systems in Ayodhya district, Uttar Pradesh.

MATERIAL AND METHODS

Study site: This study was conducted in the Ayodhya district of Uttar Pradesh which lies between 26.7730 °N and 82.1458 °E. This district is situated 93 m above MSL (Mean Sea Level). The climate of the district is tropical monsoon. The average temperature varies from 32 °C in summers to 16 °C in winters and the average annual rainfall is 1067 mm. The study area includes reserve forests, remnant vegetation patches, rivers, temple ponds, wetlands, gardens, agroforestry systems, paddy fields and human habitations.

A preliminary survey was conducted for two years (2021 to 2023) to identify the plant species diversity and associated income from these agroforestry systems practiced in Ayodhya district of U.P. which contain 11 blocks. From each block, 10 villages were selected and from each village 10 households were selected (Table 1). In total, 1100 households in 11 blocks were surveyed in which 77 households were categorized into five agroforestry systems namely agrisilviculture system, agrisilvihorticulture system, agrihorticulture system, silvipastoral system, aquasilviculture system, agroforestry systems. In addition to the agroforestry systems, these villages also have other land use systems such as wetlands, grasslands, wastelands, orchards, forest patches, riverine systems etc. interspersing across the district.

Plant species diversity: To conduct plant species inventory, 10 x 10 m quadrants were used for trees, 5 x 5 m for shrubs and 1 x 1 m for herbs. Trees (>15 cm girth at breast height of 1.37 m, >3 m height), shrubs (<15 cm girth at breast height of 1.37 m, <3 m height), saplings (5-10 cm collar diameter at base, <1 m height) and seedlings (<5 cm collar diameter at base, <20 cm height) were considered for sampling (Khumbongmayum et al 2006). The herbaceous succulents, seedlings and climbers were considered as herbs. Girth at breast height (1.3 m aboveground) was measured with the help of a measuring tape. Height of the individual tree was measured using the range finder.

The following community parameters were calculated

using the below given formulae:

- i. Importance Value Index (IVI) for trees = Relative Frequency + Relative Density + Relative Dominance
- ii. Importance Value Index (IVI) for shrubs and herbs = Relative Frequency + Relative Density
- iii. Shannon Weiner index (Shannon and Weiner 1963)

$$H' = \sum_{i=1}^s p_i \ln p_i$$

where, p_i is often the proportion of individuals belonging to the i^{th} species in the dataset and 's' is the species richness. The values usually lies between 1 and 4 where 1 shows less diversity and 4 shows high diversity.

- iv. Simpson's index (Simpson 1949)

This was calculated according to Simpson (1949) to measure the concentration of dominance (CD) of plant species.

$$CD = \sum_{i=1}^s (p_i)^2$$

where p_i is the proportion of the IVI of the i^{th} species and IVI of all the species (n_i/N). The values of Simpson's index is limited to 1 where 1 shows dominance by a single species.

- v. Pielou's evenness index (Pielou 1966) = $H'/\log_{10}N(S)$

where H' is the Shanon Weiner Index of diversity and S is the total number of species.

- vi. Sorenson's similarity coefficient (Sorenson 1948)

$$\text{Sorenson similarity coefficient} = \frac{2C}{A+B}$$

where C is the number of species common to both sites, A is the total number of species in site A, and B is the total number of species in site B. Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common.

Production and income: Production of trees was calculated using values based on the region, questionnaire survey and local knowledge. The income generated by the economic plants each plant category was calculated using the product prices derived from local market surveys.

RESULTS AND DISCUSSION

Plant diversity of agroforestry systems: Altogether the five different agroforestry systems recorded 95 plant species (76 genera, 29 families) which consisted of 12 tree species (12 genera, 6 families) and 83 herb species (66 genera, 24 families) (Fig. 1 and Table 2 and 3). The maximum plant species was in agrisilviculture system, followed by agrisilvihorticultural system, aquasilviculture, silvipastoral

Table 1. GPS location of the villages surveyed in Ayodhya District

Block name	Village name	No. of households	Latitude	Longitude
Milkipur	Baripara	10	26.564202°	81.871700°
Milkipur	Ranapur	10	26.583643°	81.959009°
Milkipur	Bansapur	10	26.562927°	81.900045°
Milkipur	Bhitauna	10	26.742714°	81.017765°
Milkipur	Banwa	10	26.595456°	81.329646°
Milkipur	Sidhauna	10	26.550323°	81.883049°
Milkipur	Chirauli	10	26.632867°	81.900787°
Milkipur	Sari	10	26.596110°	81.879465°
Milkipur	Tikra	10	26.621463°	81.914771°
Milkipur	Bawan	10	26.569380°	81.857996°
Sohawal	Mirpur Kanta	10	26.716515°	81.982337°
Sohawal	Sadhu Ka Purwa	10	26.712986°	81.960270°
Sohawal	Khirauni	10	26.739146°	81.989076°
Sohawal	Sodhiawan	10	26.692996°	82.010478°
Sohawal	Bishunpur Sara	10	26.716076°	82.021122°
Sohawal	Gopinathpur	10	26.748260°	81.988163°
Sohawal	Pilkhanwa	10	26.758623°	81.954976°
Sohawal	Tandwa	10	26.680346°	81.808784°
Sohawal	Gaurakurmiyan	10	26.739081°	81.972609°
Sohawal	Rampur Grant	10	26.725898°	81.921803°
Harigatonganj	Semra	10	26.559876°	82.011077°
Harigatonganj	Sidhaura	10	26.524173°	81.980669°
Harigatonganj	Nimdi	10	26.566036°	81.948340°
Harigatonganj	Devgiri	10	26.530400°	81.961133°
Harigatonganj	Chikhri	10	26.546718°	82.028039°
Harigatonganj	Harigatonganj	10	26.557190°	82.009841°
Harigatonganj	Bhitari	10	26.556070°	81.977499°
Harigatonganj	Jamua	10	26.636083°	82.017150°
Harigatonganj	Lakshmanpur grant	10	26.514220°	82.077785°
Harigatonganj	Paruwa	10	26.636667°	82.090833°
Mawai	Jamoli	10	26.7555291°	81.541438°
Mawai	Rewna	10	26.527393°	81.911661°
Mawai	Hariharpur	10	26.277565°	81.808056°
Mawai	Rampur Godra	10	26.303056°	81.914444°
Mawai	Ganeshpur	10	26.6420777°	81.675186°
Mawai	Badlapur	10	26.112778°	81.865647°
Mawai	Sheodhara	10	26.7614589°	81.579757°
Mawai	Saidpur	10	26.621944°	81.740278°
Mawai	Para garib shah	10	26.556596°	82.239422°
Mawai	Padera	10	26.520978°	82.270551°
Rudhuali	Sandwa	10	26.721729°	81.654335°
Rudhuali	Rampur janak	10	26.6686009°	81.6137517°
Rudhuali	Sunwa	10	26.608056°	81.691389°
Rudhuali	Sahapur	10	26.7564232°	81.754368°
Rudhuali	Kurhasadat	10	26.789458°	81.7623754°
Rudhuali	Haleemnagar	10	26.807222°	81.807778
Rudhuali	Kura sadat	10	26.784722°	81.732545°
Rudhuali	Seewan	10	26.825124°	81.709167°
Rudhuali	Khandpipra	10	26.839444°	81.768056°
Rudhuali	Manapur	10	26.724675°	81.770885°
MayaBazar	Mirzapur	10	26.727778°	81.783332°
MayaBazar	Rasoolpurkhurd	10	26.682778°	81.834722°
MayaBazar	Ichauliya	10	26.810556°	81.733333°
MayaBazar	Amauni	10	26.595833°	82.305556°
MayaBazar	Belwari khan	10	26.588889°	82.386667°
MayaBazar	Gauhaniya	10	26.566944°	82.535556°
MayaBazar	Maya Bhikhi	10	26.648889°	82.343889°

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Table 1. GPS location of the villages surveyed in Ayodhya District

Block name	Village name	No. of households	Latitude	Longitude
MayaBazar	Raja pur	10	26.606389°	82.368611°
MayaBazar	Ratanpur	10	26.631462°	82.332316°
MayaBazar	Uniyar	10	26.640833°	82.438611°
Bikapur	Arwat	10	26.617222°	82.301944°
Bikapur	Kanakpur	10	26.641389°	82.341667°
Bikapur	Toniya	10	26.726111°	82.147222°
Bikapur	Toro mafi	10	26.588333°	82.166667°
Bikapur	Umarnipipri	10	26.574722°	82.168611°
Bikapur	Newnapurab	10	26.493333°	82.180278°
Bikapur	Askaranpur	10	26.561111°	82.103611°
Bikapur	Bhawapur	10	26.648056°	82.171389°
Bikapur	Kalyanpur	10	26.613056°	82.313611°
Bikapur	Jalal pur	10	26.763889°	81.799722°
Masodha	Chandpur	10	26.612778°	82.140278°
Masodha	Baintikala	10	26.481389°	82.163333°
Masodha	Dewapur	10	26.546389°	82.129722°
Masodha	Pora	10	26.686667°	82.096389°
Masodha	Ragghupur	10	26.799722°	81.882222°
Masodha	Mohiuddinpur	10	26.705278°	82.013889°
Masodha	Sariyawa	10	26.722222°	82.077778°
Masodha	Sakhupara	10	26.710833°	82.095556°
Masodha	Amauna	10	26.698333°	82.078611°
Masodha	Bhaipur	10	26.704722°	82.021667°
Purabazar	Ganja	10	26.735556°	82.181667°
Purabazar	Madna Uparhar	10	26.699994°	82.297585°
Purabazar	Fatehpurmumtjabad	10	26.6255612°	82.282222°
Purabazar	Kutubpur	10	26.687875°	82.268578°
Purabazar	Rajepur Uparhar	10	26.7073655°	82.271828°
Purabazar	Takpura	10	26.766111°	82.202778°
Purabazar	Takpura	10	26.766111°	82.202778°
Purabazar	Hainsa	10	26.564167°	82.494722°
Purabazar	Ashifbagh	10	26.759444°	82.238889°
Purabazar	Kachhauri	10	26.659444°	82.2025124°
Purabazar	Shahjahanpur	10	26.766111°	82.196111°
Amaniganj	Hainsa	10	26.564167°	82.494722°
Amaniganj	Ranopali	10	26.758889°	82.203611°
Amaniganj	Jagdishpur	10	26.744167°	82.123889°
Amaniganj	Padkiya	10	26.651389°	81.843889°
Amaniganj	Raipatti	10	26.662778°	81.846667°
Amaniganj	Ranikpur	10	26.554444°	81.718889°
Amaniganj	Baghaura	10	26.863056°	81.387222°
Amaniganj	Gahnag	10	26.648611°	81.845556°
Amaniganj	Ram purgauhaniya	10	26.78475°	82.170109°
Amaniganj	Pal pur	10	26.827222°	81.690833°
Tarun	Jaisinghmanu	10	26.566899°	82.257970°
Tarun	Baherpur	10	26.584455°	82.258555°
Tarun	Bhaisuli	10	26.540563°	82.305661°
Tarun	Tarun	10	26.547222°	82.244722°
Tarun	Para ram	10	26.476944°	82.222314°
Tarun	Karnaipur	10	26.532255°	82.270889°
Tarun	Charawan	10	26.547222°	82.213889°
Tarun	pichhaura	10	26.556111°	82.297778°
Tarun	Paliachalpur	10	26.551117°	82.307840°
Tarun	Saraimanodhar	10	26.458611°	82.2551452°

Table 2. Vegetation species richness of selected agroforestry systems in Ayodhya District

Order	Family name	Common name	Scientific name	Habit	System			
					Agrisilviculture	Agrisilviculture	Agrihorticulture	Aquaculture
Sapindales	Meliaceae	Bakain	<i>Melia azedarah</i>	Tree	*			
Myrtales	Myrtaceae	Guava	<i>Psidium guajava</i>	Tree		*		
Sapindales	Meliaceae	Mahogany	<i>Swietenia macrophylla</i>	Tree	*			
Sapindales	Anacardiaceae	Mango	<i>Mangifera indica</i>	Tree	*	*		
Myrtales	Myrtaceae	Safeda	<i>Eucalyptus hybrid</i>	Tree	*	*		*
Fabales	Fabaceae	Shisham	<i>Dalbergia sissoo</i>	Tree	*			
Myrtales	Myrtaceae	Jamun	<i>Syzygium cumini</i>	Tree	*		*	
Lamiales	Lamiaceae	Teak	<i>Tectona grandis</i>	Tree	*			
Sapindales	Simaroubaceae	Tree of heaven	<i>Alanthus excelsa</i>	Tree	*			
Fabales	Fabaceae	Kanjji	<i>Pongamia pinnata</i>	Tree				*
Fabales	Fabaceae	Kassod	<i>Cassia siamea</i>	Tree				*
Sapindales	Meliaceae	Neem	<i>Azadirachta indica</i>	Tree				*
Fabales	Fabaceae	Alyce clover	<i>Alysicarpus monilifer</i>	Herb	*			*
Poales	Poaceae	Annual rabbits foot grass	<i>Polypogonmon speliensis</i>	Herb				*
Alismatales	Araceae	Arbi	<i>Colocasia esculenta</i>	Herb	*			
Malpighiales	Euphorbiaceae	Asthma herb	<i>Euphorbia hirta</i>	Herb	*			*
Asterales	Asteraceae	Asthmaweed	<i>Conyza bonariensis</i>	Herb	*			
Poales	Poaceae	Barnyard grass	<i>Echinochloa crus galli</i>	Herb	*			*
Poales	Poaceae	Bermuda grass/Doob grass	<i>Cynodon dactylon</i>	Herb	*			*
Poales	Poaceae	Brachiarita ramosa	<i>Brachiarita ramosa</i>	Herb	*			*
Solanales	Solanaceae	Brijjal	<i>Solanum melongena</i>	Herb	*			*
Poales	Poaceae	Browntop millet	<i>Brachiarita ramosa</i>	Herb	*			*
Malvales	Malvaceae	Burbush	<i>Triumfetta rhomboidea</i>	Herb	*			*
Solanales	Convolvulaceae	Bush morning glory	<i>Ipomoea carnea</i>	Herb				*
Brassicales	Brassicaceae	Cardamine hirsuta	<i>Cardamine hirsuta</i>	Herb	*			*
Brassicales	Cleomaceae	Celandine spider flower	<i>Cleome chelidonii</i>	Herb	*			*

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Table 2. Vegetation species richness of selected agroforestry systems in Ayodhya District

Order	Family name	Common name	Scientific name	Habit	System				
					Agrisilviculture	Agrisilviculture	Agrihorticulture	Silvipastoral	Aquaculture
Plantae	Poaceae	Chari	<i>Sorghum bicolor</i>	Herb				*	
Asterales	Asteraceae	Coatbuttons	<i>Tridax procumbens</i>	Herb	*				*
Caryophyllales	Amaranthaceae	Common lambsquarter	<i>Chenopodium album</i>	Herb	*	*			
Caryophyllales	Portulacaceae	Common purslane	<i>Portulaca oleracea</i>	Herb	*	*			
Malvales	Malvaceae	Common wireweed	<i>Sida acuta</i>	Herb	*	*			*
Asterales	Asteraceae	Congress grass	<i>Parthenium hysterophorus</i>	Herb	*				
Oxalidales	Oxalidaceae	Creeping wood sorrel	<i>Oxalis corniculata</i>	Herb	*		*		
Poales	Poaceae	Crowfoot grass	<i>Dactyloctenium aegyptium</i>	Herb	*	*		*	
Caryophyllales	Amaranthaceae	Devil's horsewhip	<i>Achyranthes aspera</i>	Herb	*	*			*
Poales	Poaceae	False amaranth	<i>Digitaria arvensis</i>	Herb	*	*			
Asterales	Asteraceae	False daisy	<i>Elipta alba</i>	Herb	*				
Solanales	Convolvulaceae	Field bindweed	<i>Convolvulus arvensis</i>	Herb	*	*			*
Asterales	Asteraceae	Flossflower	<i>Ageratum houstonianum</i>	Herb	*				
Rosales	Cannabaceae	Hemp	<i>Cannabis sativa</i>	Herb	*				
Poales	Poaceae	Giant reed	<i>Arundo donax</i>	Herb	*	*			*
Asterales	Asteraceae	Goat weed	<i>Ageratum conyzoides</i>	Herb	*	*			*
Poales	Poaceae	Goosegrass	<i>Eleusine indica</i>	Herb	*				*
Poales	Cyperaceae	Grass-like fimbry	<i>Fimbristylis miliacea</i>	Herb	*				*
Brassicales	Brassicaceae	Hairy bittercress	<i>Cardamine hirsuta</i>	Herb	*				
Poales	Cyperaceae	Haspan flats edge	<i>Cyperus haspan</i>	Herb	*	*			*
Caryophyllales	Aizoaceae	Horse pursalane	<i>Trianthema portuacastrum</i>	Herb	*	*			*
Poales	Poaceae	Indian muraina grass	<i>Ischaemum indicum</i>	Herb	*				*
Poales	Poaceae	Johnson grass	<i>Sorghum halapense</i>	Herb	*	*			*
Poales	Poaceae	Jungle Rice	<i>Echinochloa colona</i>	Herb	*	*			*
Caryophyllales	Amaranthaceae	Khaki weed	<i>Alternanthera pungens</i>	Herb	*	*			*
Poales	Poaceae	Kleberg's bluestem	<i>Dichanthium annulatum</i>	Herb	*	*			*
Poales	Poaceae	Knot grass	<i>Paspalum distichum</i>	Herb	*	*			*
Poales	Poaceae	Large crabgrass	<i>Digitaria anguinialis</i>	Herb	*	*			*

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Table 2. Vegetation species richness of selected agroforestry systems in Ayodhya District

Order	Family name	Common name	Scientific name	Habit	System				
					Agrisilviculture	Agrisilviculture	Agrihorticulture	Silvipastoral	Aquaculture
Poales	Poaceae	Little seed canary grass	<i>Phalaris minor</i>	Herb	*				
Poales	Poaceae	Maize	<i>Zea mays</i>	Herb	*	*			
Poales	Cyperaceae	Motha/Purple nutsedge	<i>Cyperus rotundus</i>	Herb	*	*			
Poales	Cyperaceae	Mullimbimby couch	<i>Cyperus brevifolius</i>	Herb	*	*			*
Solanales	Convolvulaceae	Mustard	<i>Brassica spp.</i>	Herb	*				
Solanales	Convolvulaceae	Obscure morning glory	<i>Ipomoea obscura</i>	Herb	*				
Asterales	Asteraceae	Oligochaeta	<i>Volutarella divaricata</i>	Herb	*				
Asparagales	Amaryllidaceae	Onion	<i>Allium cepa</i>	Herb	*				
Poales	Cyperaceae	Pale galingale	<i>Cyperus eragrostis</i>	Herb	*				
Lamiales	Acanthaceae	Panicled peristrophe	<i>Peristrophe paniculata</i>	Herb	*	*			
Asterales	Asteraceae	Para cress flower	<i>Blainvillea acmella</i>	Herb	*	*			
Solanales	Solanaceae	Patato	<i>Solanum tuberosum</i>	Herb	*				
Brassicales	Brassicaceae	Pepper grass	<i>Lepidium sativum</i>	Herb	*				
Gentianales	Apocynaceae	Pergularia	<i>Pergularia daemia</i>	Herb	*				
Fabales	Fabaceae	Pig's senna	<i>Cassia absus</i>	Herb	*	*			
Poales	Cyperaceae	Poorland flat sedge	<i>Cyperus compressus</i>	Herb	*	*			
Caryophyllales	Amaranthaceae	Prostrate globe-amaranth	<i>Gomphrena decumbens</i>	Herb	*	*			
Zygophyllales	Zygophyllaceae	Puncture vine	<i>Tribulus terrestris</i>	Herb	*		*		
Poales	Poaceae	Purple chloris	<i>Chloris barbata</i>	Herb	*				
Asterales	Asteraceae	Red tassel flower	<i>Emilia sonchifolia</i>	Herb	*	*			
Poales	Poaceae	Rice	<i>Oryza sativa</i>	Herb	*	*			
Poales	Cyperaceae	Ricefield flat sedge	<i>Cyperus iria</i>	Herb	*	*			*
Solanales	Convolvulaceae	Roundleaf bindweed	<i>Evolvulus nummularius</i>	Herb	*	*			*
Poales	Poaceae	Running grass	<i>Bracharia reptans</i>	Herb	*	*			*
Ericales	Primulaceae	Scarlet pimpernel	<i>Anagallis arvensis</i>	Herb	*	*			*
Fabales	Fabaceae	Showy pigeonpea	<i>Atylosia scarabaeoides</i>	Herb	*	*			*
Caryophyllales	Amaranthaceae	Slender amaranth	<i>Amaranthus viridis</i>	Herb	*	*			*
Solanales	Convolvulaceae	Slender dwarf morning glory	<i>Evolvulus alsinoides</i>	Herb	*	*			*

Cont...

Table 2. Vegetation species richness of selected agroforestry systems in Ayodhya District

Order	Family name	Common name	Scientific name	Habit	System			
					Agrisilviculture	Agrisilviculture	Silvipastoral	Aquaculture
Caryophyllales	Amaranthaceae	Spiny pigweed	<i>Amaranthus spinosus</i>	Herb	*	*		
Asterales	Asteraceae	Spiny sowthistle	<i>Sonchus asper</i>	Herb		*	*	
Poales	Poaceae	Sugercane	<i>Saccharum officinarum</i>	Herb	*	*		*
Malpighiales	Euphorbiaceae	Three-leaved caper	<i>Croton bonplandianum</i>	Herb				*
Caryophyllales	Polygonaceae	Toothed dock	<i>Rumex dentatus</i>	Herb	*			
Commelinales	Commelinaceae	Tropical spiderwort	<i>Commelia benghalensis</i>	Herb	*	*		
Fabales	Fabaceae	Urad	<i>Vigna munga</i>	Herb	*			
Poales	Cyperaceae	Variable flats edge	<i>Cyperus difformis</i>	Herb	*			
Poales	Poaceae	Wheat	<i>Triticum aestivum</i>	Herb	*	*		
Poales	Cyperaceae	White head spike sedge	<i>Cyperus kyllingia</i>	Herb	*	*		
Poales	Poaceae	Wild oat	<i>Avena ludoviciana</i>	Herb	*			
Lamiales	Orobanchaceae	Witch weed	<i>Striga asiatica</i>	Herb	*			
Poales	Poaceae	Yellow foxtail	<i>Setaria glauca</i>	Herb	*			

Cont..

and agrihorticulture (Fig. 1 and Table 2 and 3). The maximum number of families with genera and maximum number of species with families was recorded in agrisilviculture system and the minimum was recorded in agrihorticulture system (Table 3). The maximum number of tree species was recorded in agrisilvicultural system and the minimum was recorded in silvipastoral system (Table 4). The maximum number of herb species was recorded in agrisilviculture and the minimum in agrihorticulture (Table 4).

The highest vegetation species richness was in the agrisilviculture, followed by agrisilviculture, silvipastoral, aquasilviculture and the least in agrihorticulture (Table 5). This plant species in agrisilviculture system in the current study is lower than the plant diversity (101 plant species) and vegetation species richness (69.33) found in the same system in Assam (Yashmita-Ulman et al 2021) and higher than that of swidden agroforestry system of Peru (Wezel and Ohi 2005). These differences in species richness might be due to the people's preferences for tree species, topographic and climatic factors of the study sites. The highest tree species richness was recorded in agrisilviculture system, followed by agrisilviculture, aquaculture and agrihorticulture and silvipastoral system (Table 5). The maximum tree density was in agrisilviculture, agrisilviculture, silvipastoral, agrihorticulture and aquaculture (Table 5). The maximum tree basal area was recorded in silvipastoral system, followed by agrisilviculture, agrisilviculture, agrihorticulture, aquasilviculture (Table 5). The maximum tree Shannon Weiner Index was in agrisilviculture, followed by agrisilviculture, agrihorticulture, aquaculture (Table 5). The maximum tree Simpson's Dominance index was in silvipastoral, agrihorticulture, aquaculture, agrisilviculture, agrisilviculture (Table 5). The tree evenness index was the highest for the agrisilviculture, followed by agrisilviculture, and aquasilviculture (Table 5).

The highest tree stand density was recorded in silvipastoral system and lowest was recorded in both agrihorticulture and aquasilviculture system (Fig. 2). The highest basal area was recorded in silvipastoral system and the lowest was recorded in both agrihorticulture and aquaculture system (Fig. 2). *Eucalyptus* spp. in silvipastoral system recorded the highest tree density and the lowest was recorded by *Dalbergia sissoo* in agrisilviculture system (Table 6). The highest tree basal area was recorded in *Eucalyptus* spp. in silvipastoral system and the lowest was recorded in *Magnifera indica* in agrisilviculture system (Table 6). *Eucalyptus* spp., *Tectona grandis*, *Swietenia macrophylla*, *Melia azedarah*, and *Ailanthus excelsa* were the top five ranked woody species with the highest IVI values.

Table 3. Overall families with genera and species richness of selected agroforestry systems in Ayodhya District

Family	Overall		Agrisilvicultural		Agrihorticulture		Agrisilvihorticulture		Silvipastoral		Aquasilviculture	
	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species
Acanthaceae	1	1					1	1				
Aizoaceae	1	1			1	1	1	1				
Amaranthaceae	5	6	3	4	1	1	5	5			2	2
Amaryllidaceae	1	1	1	1								
Anacardiaceae	1	1	1	1	1	1	1	1	1	1		
Apocynaceae	1	1	1	1								
Araceae	1	1	1	1					1	1		
Asteraceae	9	10	7	8	1	1	2	2	1	1	1	1
Brassicaceae	2	3	2	3								
Cannabaceae	1	1	1	1			1	1				
Cleomaceae	1	1	1	1								
Commelinaceae	1	1	1	1	1	1						
Convolvulaceae	4	6	4	4			2	2			1	1
Cyperaceae	2	9	1	7	1	1	5	5			2	2
Euphorbiaceae	2	2	1	1			1	1	1	1		
Fabaceae	6	7	5	5			2	2	4	4	2	2
Lamiaceae	1	1	1	1			1	1	1	1		

Table 4. Tree and herb wise families with genera and species richness of selected agroforestry systems in Ayodhya district

Family	Overall		Agrisilvicultural		Agrihorticulture		Agrisilvihorticulture		Silvipastoral		Aquasilviculture	
	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species	No. of genera	No. of species
Tree												
Anacardiaceae	1	1	1	1	1	1	1	1				
Fabaceae	3	3	1	1							2	2
Lamiaceae	1	1	1	1			1	1				
Meliaceae	3	3	2	2							1	1
Myrtaceae	3	3	1	1	1	1	1	2	1	1		
Simaroubaceae	1	1	1	1								
Total	12	12	7	7	2	2	3	4	1	1	3	3
Herb												
Acanthaceae	1	1					1	1				
Aizoaceae	1	1			1	1	1	1	1	1		
Amaranthaceae	5	6	3	4	1	1	5	5	1	1	2	2
Amaryllidaceae	1	1	1	1								
Apocynaceae	1	1	1	1								
Araceae	1	1	1	1								
Asteraceae	9	10	7	8	1	1	2	2	2	2	1	1
Brassicaceae	2	3	2	3								
Cannabaceae	1	1	1	1			1	1				
Cleomaceae	1	1	1	1								
Commelinaceae	1	1	1	1	1	1						
Convolvulaceae	4	6	4	4			2	2	1	1	1	1
Cyperaceae	2	9	1	7	1	1	1	5	1	2	2	2
Euphorbiaceae	2	2	1	1			1	1	2	2		
Fabaceae	4	4	4	4			2	2	1	1		
Malvaceae	2	2	2	2			1	1	1	1		
Orobanchaceae	1	1	1	1							1	1
Oxalidaceae	1	1			1	1						
Poaceae	20	25	17	21	5	5	11	13	6	6	6	7
Polygonaceae	1	1	1	1								
Portulacaceae	1	1	1	1			1	1				
Primulaceae	1	1	1	1								
Solanaceae	1	2	1	2	1	1						
Zygophyllaceae	1	1	1	1	1	1						
Total	65	83	53	67	13	13	29	35	16	17	14	15

The IVI, tree density, tree basal area, Shannon Weiner index, Simpson's Dominance index, Pielou's Evenness index suggest that these systems are dominated by a few tree species such as *Eucalyptus* spp., *Tectona grandis*, and *Mangifera indica* (Table 5 and 6). The farmers prefer these trees as the timber of these trees fetch high market price.

The maximum herb species richness was in agrisilviculture, followed by agrisilvihorticulture, silvipastoral, agrihorticulture, aquaculture (Table 5). The maximum herb density was in agrisilvihorticulture, followed by silvipastoral system, agrisilviculture, agrihorticulture and aquaculture (Table 5). The highest herb density was recorded by *Triticum aestivum* and the lowest was recorded in *Amaranthus viridis*

in agrisilviculture system (Table 6). The maximum herb Shannon Weiner Index was recorded in agrisilviculture system, followed by agrisilvihorticulture, aquaculture, agrihorticulture and silvipastoral (Table 5). The maximum herb Simpson's dominance index was in silvipastoral system, followed by agrisilvihorticulture, agrihorticulture (Table 5). The highest herb evenness index was in aquasilviculture, agrihorticulture, agrisilvihorticulture (Table 5). The Sorenson's Similarity index revealed that all the agroforestry systems had a very low degree of similarity between the vegetation species (Table 7). Shastri *et al.* (2002) also found very low similarity between different agroforestry systems in Karnataka.

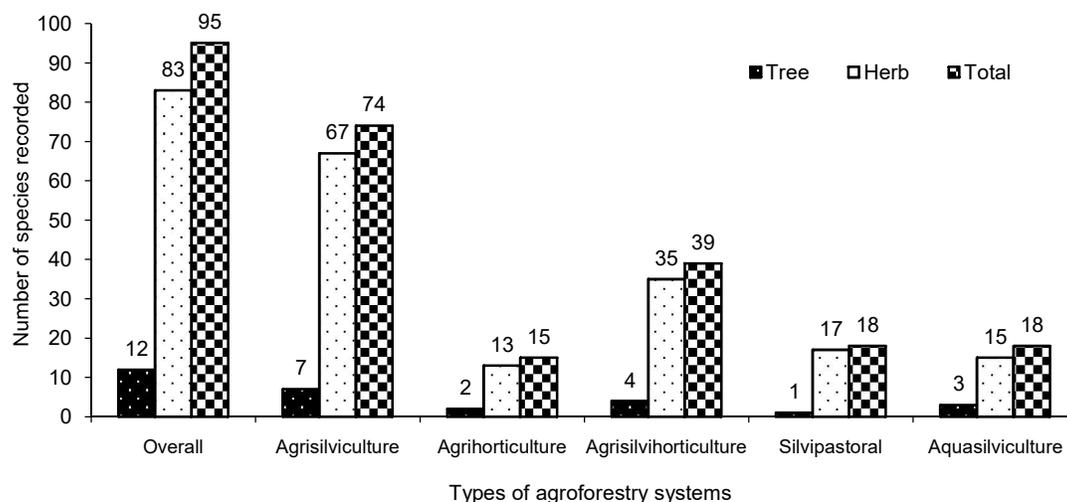


Fig. 1. Vegetation species richness of selected agroforestry systems in Ayodhya district

Table 5. Community characteristics of selected agroforestry systems in Ayodhya district

Parameters	Types of agroforestry systems studied				
	Agrisilviculture	Agrisilvihorticulture	Agrihorticulture	Silvipastoral	Aquasilviculture
Vegetation species richness	42.72±3.92	19±4.50	9.5±0.5	12	10±2
Tree species richness	2.72±0.30	2.66±0.66	1	1	2±1
Tree density (individuals ha ⁻¹)	35210.81±34812.22	427.77±14.69	250±50	375±75	250±50
Tree Basal area (m ² ha ⁻¹)	1.79±0.06	1.68±0.25	0.92±0.03	2.11±0.65	0.81±0.09
Tree Shannon Weiner index	0.78±0.12	0.85±0.17	0.33±0.33	0	0.34±0.34
Tree Simpson's Dominance index	0.46±0.07	0.46±0.05	0.76±0.24	1	0.75±0.25
Tree Evenness index	0.67±0.08	0.94±0.03	0	0	0.31±0.31
Herb Species richness	40±3.751	16.33±3.84	8.5±0.5	11	8±1
Herb density (individuals ha ⁻¹)	382820.72±18068.32	1702638.89±1275557	152500±32500	453125±60625	152500±5000
Herb Shannon Weiner index	1.25±0.04	0.97±0.13	0.84±0.005	0.72±0.05	0.86±0.08
Herb Simpson's Dominance index	0.10±0.01	0.19±0.06	0.17±0.005	0.34±0.03	0.15±0.04
Herb Evenness index	0.34±0.005	0.35±0.02	0.39±0.009	0.29±0.02	0.41±0.01

Table 6. Stand density, basal area and IVI of selected agroforestry systems in Ayodhya district

Scientific name	Agroforestry systems														
	Agrisilviculture			Agrisilviculture			Agrihorticulture			Silvipastoral			Aquasilviculture		
	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI
Tree															
<i>Alianthus excelsa</i>	17.59	0.06	13.34												
<i>Azadirachta indica</i>															
<i>Cassia siamea</i>															
<i>Dalbergia sissoo</i>	15.74	0.05	11.76												
<i>Eucalyptus hybrid</i>	266	1.13	198.04	250	0.98	169.84			400	2.33	300				
<i>Magnifera indica</i>	0.92	0.01	1.22	83.33	0.35	66.95	200	0.75	230						
<i>Melia azedaraah</i>	22.22	0.12	18.98												
<i>Pongamia pinnata</i>															
<i>Psidium guajava</i>	26.85	0.09	19.58	66.66	0.15	41.53								200	0.55
<i>Swietenia macrophylla</i>															
<i>Syzygium cumini</i>									50	0.15	70				
<i>Tectona grandis</i>	48.14	0.19	37.11	33.33	0.1	22.34									
Herb															
<i>Achyranthes aspera</i>	1417		1.67	2500		1.91									
<i>Ageratum conyzoides</i>	500		0.39												
<i>Ageratum houstonianum</i>	1000		1.04												
<i>Allium cepa</i>	1917		1.54												
<i>Alternanthera pungens</i>				1667		1.70									
<i>Alysicarpus monilifer</i>	583		0.67	833		1.50			4166		3.73				
<i>Amaranthus spinosus</i>	333		0.34	1250		1.60									
<i>Amaranthus viridis</i>	83		0.28						7500		7.29				
<i>Anagallis arvensis</i>	2417		1.93												
<i>Arundo donax</i>	250		0.32						5000		3.91				
<i>Atylosia scarabaeoides</i>	583		0.90												

Cont...

Table 6. Stand density, basal area and IVI of selected agroforestry systems in Ayodhya district

Scientific name	Agroforestry systems														
	Agrisilviculture			Agrilivihorticulture			Agrihorticulture			Silvipastoral			Aquasilviculture		
	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI
<i>Avena ludoviciana</i>	333		0.61												
<i>Blainvillea acmella</i>				2500		1.91									
<i>Brachiaria ramosa</i>	833		1.00	1250		1.60	2500		6.18						
<i>Brachiaria reptans</i>	1750		1.49	3750		3.51				5000		6.77			
<i>Brassica nigra</i>	2750		2.01												
<i>Camelina benghalensis</i>	917		0.49												
<i>Cannabis sativa</i>	1667		2.00	2500		1.91									
<i>Cardamine hirsuta</i>	1917		1.54												
<i>Cassia absus</i>	500		0.39	3333		2.11									
<i>Chenopodium album</i>	2167		2.12	3750		3.51	3750		7.00						
<i>Chloris barbata</i>	3333		2.69												
<i>Cleome chelidonii</i>	417		0.63												
<i>Colocasia esculenta</i>	1917		1.27												
<i>Commelina benghalensis</i>	5417		3.74				10000		11.10						
<i>Convolvulus arvensis</i>	4500		4.30	6667		6.82				1666		6.06			
<i>Conyza bonariensis</i>	583		0.93												
<i>Cyperus rotundus</i>	16000		11.70												
<i>Croton bonplandianum</i>															
<i>Cynodon dactylon</i>	20083		14.85	21250		12.99	41250		36.14		4166		3.73		
<i>Cyperus compressus</i>	1667		1.47	2500		3.20									
<i>Cyperus difformis</i>	417		0.36												
<i>Cyperus eragrostis</i>	500		0.39												
<i>Cyperus haspan</i>	1667		1.73	1667		1.70									
<i>Cyperus iria</i>	2917		2.58	10417		5.14									
<i>Cyperus kyllingia</i>	417		0.36	2083		1.80									
<i>Cyperus rotundus</i>				8750		7.33	6250		8.64		8333		7.47		

Cont..

Table 6. Stand density, basal area and IVI of selected agroforestry systems in Ayodhya district

Scientific name	Agroforestry systems											
	Agrisilviculture			Agrihorticulture			Silvipastoral			Aquaasilviculture		
	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI
<i>Dactyloctenium aegyptium</i>	5750		4.09	4167		3.61	8750		10.28	4166		3.73
<i>Dalbergia sissoo</i>	85		0.28									
<i>Dichanthium annulatum</i>	500		0.39	3333		2.11						
<i>Digera arvensis</i>	3500		2.47				1250		5.36			
<i>Digitaria sanguinalis</i>	1833		1.51	1667		1.70						
<i>Echinochloa colona</i>	11917		7.77	5833		5.32						
<i>Echinochloa crusgalli</i>	1000		1.04	10833		5.25						
<i>Eclipta alba</i>	500		0.65									
<i>Eleusine indica</i>	1750		1.49									
<i>Emilia sonchifolia</i>	667		0.43									
<i>Euphorbia hirta</i>	1167		0.82	1667		1.70				2500		3.38
<i>Evolvulus alsinoides</i>				417		1.40						
<i>Evolvulus nummularius</i>	500		0.65									
<i>Gomphrena decumbens</i>				1250		1.60						
<i>Ipomoea obscura</i>	417		0.36									
<i>Lepidium sativum</i>	167		0.30									
<i>Magnifera indica</i>				833		1.50			6.18			
<i>Oryza sativa</i>	57000		20.62	38750		13.38						
<i>Oxalis corniculata</i>									7.01			
<i>Parthenium hysterophorus</i>	750		0.45									
<i>Pergularia daemia</i>	417		0.36									
<i>Peristrophe paniculata</i>				2083		3.10						
<i>Phalaris minor</i>	1000		1.30							2500		3.38
<i>Polypogon monspeliensis</i>												

Cont...

Table 6. Stand density, basal area and IVI of selected agroforestry systems in Ayodhya district

Scientific name	Agroforestry systems														
	Agrisilviculture			Agrisilviculture			Agrihorticulture			Silvipastoral			Aquaasilviculture		
	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI	Density (ha ⁻¹)	Basal area (m ² ha ⁻¹)	IVI
<i>Portulaca oleracea</i>	250		0.85	417		1.40									
<i>Psidium guajava</i>				833		1.50									
<i>Rumex dentatus</i>	917		1.28												
<i>Saccharum officinarum</i>	73000		27.07	75833		28.96									
<i>Setaria glauca</i>	750		0.71												
<i>Sida acuta</i>	750		0.45	2500		3.20				5000		3.91			
<i>Solanum melongena</i>	4000		3.12				18750		25.93						
<i>Solanum tuberosum</i>	4333		2.15												
<i>Sonchus asper</i>				833		1.50			14.82	833		3.03			
<i>Sorghum bicolor</i>										398333		115			
<i>Sorghum halapense</i>	2250		1.88	5000		3.82									
<i>Striga asiatica</i>	1000		1.04												
<i>Tectona grandis</i>	90		0.28												
<i>Trianthema portuacastrum</i>	2167		2.39	1667		1.70			14.82	2500		3.38			
<i>Tribulus terrestris</i>	250		0.32				5000		7.82						
<i>Tridax procumbens</i>	500		0.65							1666		3.20			
<i>Triticum aestivum</i>	105167		30.06	159167		44.17									
<i>Triumfetta rhomboidea</i>	1167		1.08												
<i>Vigna munga</i>	14833		6.94												
<i>Volutarella divaricata</i>	250		0.32												
<i>Zea mays</i>	8500		6.37	14583		12.66			38.67	31250					

Production and income from agroforestry systems:

Out of the five agroforestry systems found in the study area, three systems namely agrisilviculture, agrihorticulture and agrisilvihorticulture are used for cultivating rice. The highest average productivity and average income of *Oryza sativa* was found in agrisilviculture, followed by agrisilvihorticulture and agrihorticulture system (Table 8). The highest average productivity and income of *Triticum aestivum* (wheat) was recorded in agrihorticulture and agrisilviculture, followed by agrisilvihorticulture (Table 8). *Triticum aestivum* is grown with *Eucalyptus* spp. and *Tectona grandis* in the study area. Kar et al (2022) has reported that in Madhya Pradesh, the productivity of *Triticum aestivum* grown with *Dalbergia sissoo* is 27.60 q

ha⁻¹. The average productivity for *Brassica nigra* was highest in agrihorticulture system (Table 8). The average productivity and average income of *Eucalyptus* spp. was the highest in agrisilviculture system followed by agrisilvihorticulture system (Table 8). A similar study in Andhra Pradesh reported that the income generated by *Eucalyptus* spp. after four years in agrisilviculture system was Rs. 27, 440/-. Similarly, in agrisilviculture system, the average productivity and average income was the highest from *Tectona grandis*, followed by *Swietenia mahogany*, *Dalbergia sissoo* and *Ailanthus excelsa* (Table 8). In agrisilvihorticulture, the average productivity and average income was highest from *Emblca officinalis* followed by *Psidium guava* (Table 8).

Table 7. Sorenson's similarity index of selected agroforestry systems in Ayodhya district

Agroforestry systems	Agrisilviculture	Agrihorticulture	Agrisilvihorticulture	Silvipastoral	Aquasilviculture
Agrisilviculture	0.00				
Agrihorticulture	0.24	0.00			
Agrisilvihorticulture	0.54	0.33	0.00		
Silvipastoral	0.28	0.30	0.42	0.00	
Aquaculture	0.19	0.12	0.21	0.11	0.00

Table 8. Productivity and income from products sold from various agroforestry systems in Ayodhya district

Crop name	Agrisilviculture		Agrihorticulture		Agrisilvihorticulture	
	Productivity mean (quintal)	Income by sale of products (Rs.)	Productivity mean (quintal)	Income by sale of products (Rs.)	Productivity mean (quintal)	Income by sale of products (Rs.)
Cereals						
<i>Oryza sativa</i>	40.53	46875	23.75	18900	33	46200
<i>Triticum aestivum</i>	27.55	46862	30.75	39600	26.83	34800
<i>Brassica nigra</i>	4.16	13775	5.50	5700		
Cash crops						
<i>Saccharum officinarum</i>	176.50	42100				
Vegetables						
<i>Solanum melongena</i>	11.50	144				
Trees						
<i>Eucalyptus globulus</i>	9.02	20796.61			6.29	18560
<i>Tectona grandis</i>	1.56	74083.33				
<i>Ailanthus excelsa</i>	0.40	9533.33				
<i>Swietenia mahogany</i>	0.80	29142.85				
<i>Dalbergia sissoo</i>	0.53	20516.67				
Fruits (kg)						
<i>Psidium guajava</i>					108	1563
<i>Emblca officinalis</i>					330	3350
<i>Magnifera indica</i>			161.40	2869		

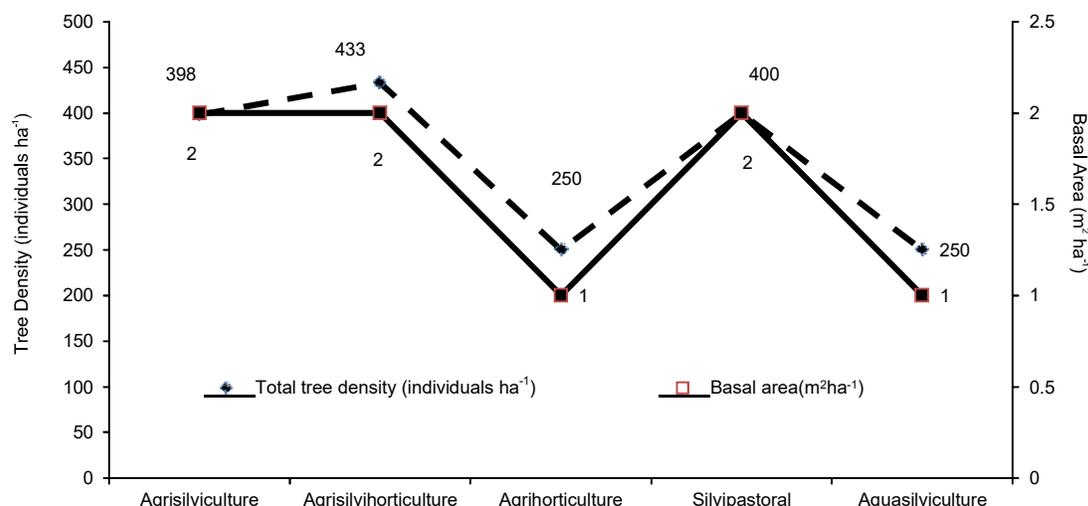


Fig. 2. Stand density (individuals ha⁻¹) and basal area (m²ha⁻¹) of tree species in selected agroforestry systems in Ayodhya district

CONCLUSION

The five different agroforestry systems of this region have conserved a high amount of plant diversity. But still there is a scope for conserving more species as currently these systems seem to be more inclined towards having a few dominant species alone as they are preferred by the local farmers. These agroforestry systems are also associated with high income earning opportunities. Shifting towards a more diverse plant species cultivation by including indigenous tree species will be recommended for future conservation practices. Preference must be given to planting of multipurpose trees which provide multiple benefits including production, protection and income generation. Timely and scientific management practices are required for improvement of yield and system functioning.

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