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Prevalence, species composition and edaphic characteristics of agroforestry systems in the Central Kashmir Himalaya

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Research Article

Keywords: Agroforestry systems, Cropping intensity, Soil fertility, Homegarden, Nutrient dynamics, Sustainable land management

Posted Date: August 15th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10046541/v1

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Additional Declarations: No competing interests reported.

"Prevalence, species composition and edaphic characteristics of agroforestry systems in the Central Kashmir Himalaya"

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ABSTRACT

The present study was conducted in District Ganderbal, Jammu and Kashmir, to identify prominent agroforestry systems, assess their adoption pattern, cropping intensity, and evaluate their influence on soil properties. A total of 112 households were surveyed using structured questionnaires and field observations. Four major agroforestry systems were identified, namely Homegarden, Agrihortisilviculture, Hortisilvipasture, and Agrisilviculture (boundary plantation). Homegarden was the most widely adopted system (30.36% households), whereas Hortisilvipasture occupied the largest proportion of total agroforestry area (30.00%). The systems comprised diverse combinations of timber trees, fruit trees, agricultural crops, and forage species, reflecting their multifunctional role in sustaining rural livelihoods. Cropping pattern analysis revealed the cultivation of cereals, pulses, vegetables, forage, and oilseed crops across different systems. The highest cropping intensity was recorded in Agrisilviculture (179.21%), followed by Homegarden (173.83%), Hortisilvipasture (169.38%), and Agrihortisilviculture (162.58%), with an overall mean cropping intensity of 171.75%, indicating efficient land utilization through integration of annual and perennial components. Soil properties varied significantly among agroforestry systems and soil depths. Soil pH increased with depth, whereas electrical

conductivity, organic carbon, and available nitrogen, phosphorus, and potassium decreased from 0–30 cm to 30–60 cm depth. Homegarden recorded the highest organic carbon (1.92 and 1.02%), available nitrogen (329.21 and 285.29 kg ha^{-1}), phosphorus (39.11 and 34.79 kg ha^{-1}), and potassium (298.73 and 269.99 kg ha^{-1}) at respective depths. Overall, soil fertility followed the order: Homegarden > Agrihortisilviculture > Hortisilvipasture > Agrisilviculture. The study highlights the ecological and productive benefits of diversified agroforestry systems in enhancing soil fertility, optimizing land use, and supporting sustainable livelihoods in the Kashmir Himalaya.

Key words: *Agroforestry systems; Cropping intensity; Soil fertility; Homegarden; Nutrient dynamics; Sustainable land management*

Introduction

Globally, agroforestry systems (AFS) are estimated to span approximately 1.6 billion hectares, with the majority around 78% concentrated in tropical regions, while the remaining 22% are distributed across temperate zones. (Nair *et al.,* 2022). The Indian Himalayan region represents one of the planet's most ecologically diverse, resource-rich, yet environmentally sensitive biogeographic zones. Within this landscape, indigenous communities have developed and sustained a wide array of traditional land use systems, among which agroforestry holds a particularly enduring legacy. Rooted in centuries-old ecological knowledge, these systems are distinguished by the spontaneous integration of native tree species into agricultural landscapes evolving organically rather than through deliberate intensification. Ranging from simpler configurations like silvopastoral systems and boundary plantations to intricate and economically resilient models such as agri-horti-silvicultural systems and multifunctional home gardens, traditional agroforestry in the Himalayas exemplifies a dynamic interface between biodiversity conservation and livelihood sustainability (Verma K *et al*., 2024). The main purpose of a classification scheme is to provide a practical framework for the synthesis and analysis of the information about existing agroforestry systems (AFS) and the development of new and promising ones (Nair *et al.,* 2021). These diverse, tribe-specific traditional farming systems have

significantly enriched the region's cultural and agro-biodiversity. A broad spectrum of indigenous millets, cereals, pulses, vegetables, and fruit cultivars have historically dominated these agricultural landscapes, offering vital ecological resilience and adaptive capacity in the face of extreme environmental events and climate variability (Patel SK *et al.,* 2024). In the humid and subhumid tropics, prevalent agroforestry systems encompass shifting cultivation, tree-based intercropping, homegardens, and shaded perennial crop associations. In contrast, agroforestry practices in the semiarid and arid tropics are primarily characterized by silvopastoral systems, widespread tree intercropping, and the strategic use of windbreaks. Temperate regions, on the other hand, typically feature systems such as alley cropping, forest farming, silvopasture, riparian buffer zones, and windbreaks as key agroforestry approaches (Nair *et al.,* 2022).

Beenish *et al.* (2025) reported that fruit tree-based agroforestry systems significantly improved soil physico-chemical properties and carbon sequestration compared with sole cropping systems. Agroforestry plots exhibited higher organic carbon, available nitrogen, phosphorus, potassium, and soil moisture, along with lower bulk density, pH, and electrical conductivity. The study also recorded greater biomass and soil carbon stocks under agroforestry, with the apricot-rajmash system showing the highest total carbon stock (52.88 t ha^{-1}). These findings highlight the potential of agroforestry systems to enhance soil fertility, increase carbon storage, and promote climate-resilient agriculture in the Himalayan region. The Kashmir Valley exhibits a deep-rooted connection between rural farming communities and agroforestry land-use systems, underpinned by a strong emphasis on the multifunctionality of agroforestry. Agroforestry has long been an integral part of rural life in the region, with traditional systems such as agri-silvi-horticulture and homestead forestry widely practiced (Islam *et al.,* 2012). Commonly integrated woody and fruit tree species include *Salix alba*, *Populus deltoides*, *Ulmus villosa*, *Robinia pseudoacacia*, *Populus nigra*, *Juglans regia*, *Morus alba*, *Ailanthus altissima*, *Pyrus communis*, *Prunus persica*, and *Prunus armeniaca*. Despite the diverse ecological and socio-economic benefits these systems offer, their adoption remains significantly lower than projected (Banyal *et al.,* 2011). While numerous global land use

systems have been assessed for their economic potential, similar comprehensive evaluations are still needed for agroforestry practices in Kashmir. Bhat *et al.* (2025) reported that fruit tree performance was significantly enhanced under agroforestry systems compared with sole apricot cultivation. Among the different agroforestry combinations evaluated, the apricot-rajmash system recorded the highest fruit yield (8.01 t ha^{-1}), substantially exceeding that of the control treatment comprising only apricot trees (3.73 t ha^{-1}). The study further highlighted a trade-off between pulse productivity and the long-term ecological benefits associated with agroforestry. Although sole cropping produced higher short-term pulse yields, the integration of fruit trees with pulse crops contributed to improved soil health, enhanced biodiversity, greater land-use efficiency, and increased ecosystem resilience. These findings emphasize the potential of agroforestry systems as a sustainable land management approach capable of simultaneously supporting agricultural production and facilitating the restoration of degraded landscapes. Given the prominent land use patterns, diverse landscapes, and productive agroforestry systems in the Kashmir Valley, there exists substantial potential for enhancing rural livelihoods through the development and integration of agroforestry-based opportunities. To effectively promote the adoption of agroforestry, it is essential to understand the psychological and socioeconomic factors that influence farmers' decisions. Thus the present study is designed to highlight the prominent agroforestry systems, their composition and edaphic characteristics to seek the attention from practitioners, scientists and policy makers for its further development and strengthening.

Material and Methods:

The experimental site i.e. District Ganderbal is at the elevation of 1650-3000 meter above mean sea level (MSL). Agriculture serves as the primary livelihood in Ganderbal district, with over 80% of the population directly engaged in agricultural activities, positioning it as a key agrarian district within the Union Territory of Jammu and Kashmir. The region is characterized by distinctive agro-climatic conditions that support the cultivation of a wide array of horticultural crops. In addition to major fruit crops such as

apple, pear, cherry, and walnut, the district is also known for producing. Multi-stage random method (Ray and Mondol, 2004) was used to select the blocks, villages and the households. The first stage was the random sampling of C.D. blocks namely, Ganderbbal, Lar, Wakura and Kangan in the district. The second stage involved the simple random sampling of 12 villages from Four Blocks. A total of 112 households were surveyed, representing a sampling intensity of 5%. Respondents primarily included household heads or the eldest available family members. A schematic representation of the sampling framework is illustrated in Figure 1. Data were gathered through primary field surveys and secondary sources. Primary data collection involved household-level surveys using structured interview schedules, along with non-participant observation (Kumar, 2012). These methods provided rich, context-specific insights into agroforestry adoption and livelihood dynamics. Secondary data were collected from a range of scholarly and institutional sources, including peer-reviewed journals, previous research studies, annual reports, and technical manuscripts relevant to agroforestry and rural livelihoods. This approach facilitated a deeper understanding of household practices and their lived experiences with agroforestry systems.

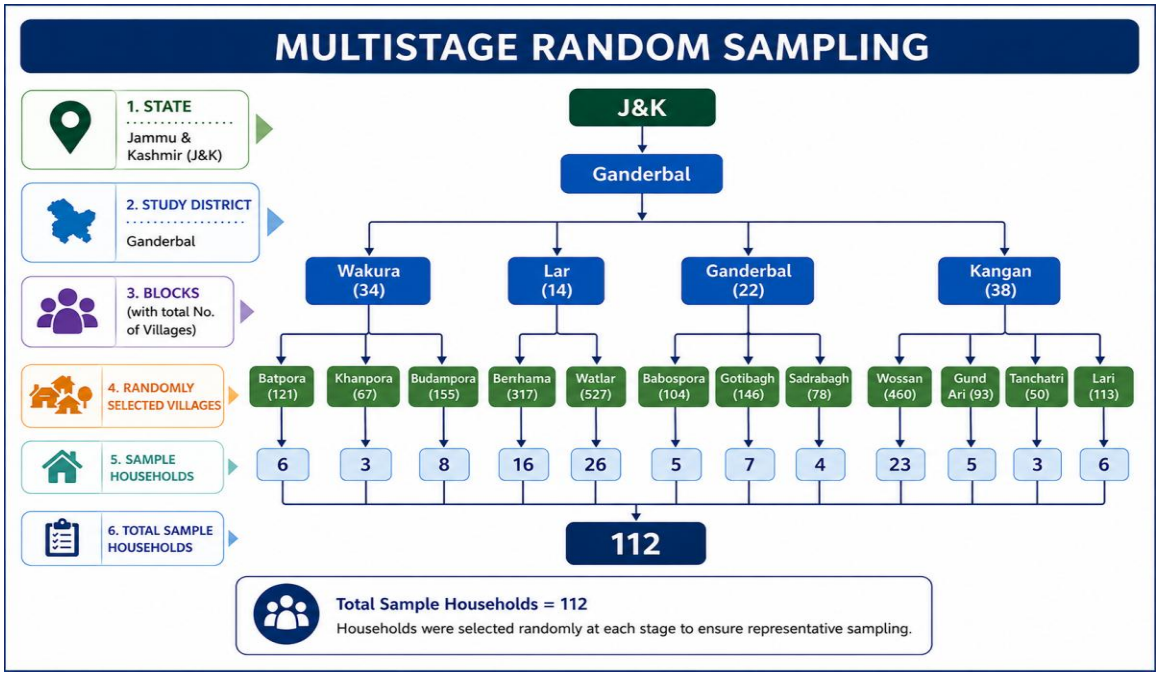


Fig. 1

Prominent Agroforestry systems

Prominent agroforestry systems were identified by analyzing their core components and aligning with the accepted definition, intentional integration of woody perennials with crops and/or livestock on the same land unit in a spatial or temporal sequence, facilitating both ecological and economic interactions (Rao, 2000). Information on the land area under each agroforestry system was obtained directly from the respondents using the structured interview schedule. Seasonal observations were made during both Rabi and Kharif periods to document tree and crop species combinations practiced by the sampled households. This enabled accurate profiling of seasonal agroforestry patterns.

Cropping Intensity

Cropping intensity was calculated using the standard formula:

$$\text{Cropping intensity} = \frac{\textit{Gross cropped area}}{\textit{Net sown area}} \times 100$$

Where:

- **Gross Cropped Area** is the total area sown once or multiple times in a year.
- **Net Sown Area** is the total area sown, counting each unit of land only once regardless of cropping frequency (Dalrymple, 1971).

Soil Sampling and Analysis

Soil samples were collected from five randomly selected points within each agroforestry system. Sampling was performed at a soil depth of: 0–30 cm and 30-60 cm. The collected samples were thoroughly homogenized, air-dried, and ground using a pestle and mortar. The ground samples were then passed through a 2 mm mesh sieve to ensure uniformity, and the processed samples were stored in labelled paper bags for subsequent chemical analysis.

- Organic carbon content was estimated using the Walkley and Black rapid titration method (Jackson, 1958).
- Available nitrogen was determined using the alkaline permanganate method developed by Subbiah and Asija (1956).

- Available phosphorus was analyzed following the Olsen's method (Olsen *et al.,* 1954), while available potassium was quantified through flame photometry after extraction with neutral normal ammonium acetate (Jackson, 1973).

Statistical Analysis:

The data were collected and subjected to R software for statistical analysis.

Results and Discussions:

Prominnet Agroforestry systems adopted

Table 1, depicts the prominent agroforestry systems prevailing in district Ganderbal along with their associated trees, fruit trees, agricultural, and forage components during *kharif* and *rabi* seasons. Four major agroforestry systems were identified, namely Homegardens, Agrihortisilviculture**,** Hortisilvipasture**,** and Agrisilviculture (boundary plantation)**,** each characterized by a distinct combination of woody perennials and crop components. The Homegarden system exhibited high species diversity and structural complexity, integrating timber, fuelwood, fruit trees, vegetables, and root crops within a confined landholding. Tree species such as *Salix fragilis*, *Populus balsamifera*, *Ailanthus altissima*, *Aesculus indica*, *Morus alba*, *Ulmus villosa*, and *Robinia pseudoacacia* were commonly observed. Fruit trees included pomegranate, apple, pear, plum, cherry, peach, walnut, and grapevine. The crop component consisted of a wide array of vegetables and cucurbits during *kharif*, while *rabi* crops were dominated by peas, onion, garlic, radish, carrot, turnip, and leafy vegetables, indicating intensive household-level production for subsistence and income generation. The Agrihortisilviculture system was found to be highly diversified, comprising a wide range of timber and multipurpose tree species such as *Populus deltoides*, *Populus nigra*, *Salix alba*, *Robinia pseudoacacia*, *Ailanthus altissima*, and *Ulmus villosa*. This system also supported several fruit tree species including *Malus domestica*, *Pyrus communis*, *Prunus avium*, *Prunus persica*, *Prunus armeniaca*, *Juglans regia*, *Prunus amygdalus*, and *Vitis vinifera*. The agricultural component under this system was dominated by cereal, pulse, vegetable, and oilseed crops during the *kharif* season, while *rabi* crops mainly included oats, mustard, peas, onion, garlic, radish, turnip,

carrot, and leafy vegetables, indicating intensive and year-round land use. The Agrisilviculture system**,** mainly practiced as boundary plantation, involved a relatively simpler structure with limited tree species such as *Populus deltoides*, *Populus balsamifera*, *Salix alba*, *Salix fragilis*, and *Ulmus villosa*. This system largely supported cereal-based cropping, with *Oryza sativa* being the dominant *kharif* crop, while oats and mustard varieties were commonly cultivated during the *rabi* season. The Hortisilvipasture system was characterized by the integration of forest tree species such as *Populus* spp., *Salix* spp., *Ulmus villosa*, *Robinia pseudoacacia*, and *Ailanthus altissima* with fruit trees like apple, pear, apricot, peach, cherry, pomegranate, and grapevine. The crop component under this system was predominantly composed of forage species including *Trifolium repens*, *Trifolium pratense*, *Amaranthus* spp., *Lolium perenne*, *Lolium multiflorum*, *Bromus japonicus*, *Dactylis glomerata*, and *Festuca* species, reflecting its major role in supporting livestock-based livelihoods. During the *rabi* season, oats (*Avena sativa*) was the principal crop grown. Traditional agroforestry systems integrating trees such as *Populus deltoides, Salix alba, and Robinia pseudoacacia* with field crops have been documented in the Kashmir valley, highlighting similar system components as observed in this study (Mughal and Bhattacharya, 2002). *Salix alba* has been identified as a dominant species in mapped agroforestry areas of the Western Himalaya, accounting for a significant proportion of agroforestry cover (Rizvi *et al*., 2021). Silvopastoral systems with willow (*Salix alba*) intermixed with fodder crops like maize have been shown to be productive and economically viable in the Kashmir valley context (Bhat and Islam, 2019).

Table 1: Prominent agroforestry systems in district Ganderbal

S. No.	Nature of system	Tree Component	Fruit tree Component	Crop Component	
				Kharif	Rabi
1.	**Agrihortisilviculture- System**	*Populus deltoides, Populus nigra., Salix alba, Robinia pseudoacacia, Ailanthus altissima, Ulmus villosa,*	*Malus domestica,, pyrus communis Prunus avium, Prunus persica, Prunus armeniaca, Juglans regia, Prunus amygdalus, Vitus vinifera*	*Phaseolus vulgaris, Vigna radiata, Zea mays, Glycine max, Brassica oleracea var.gongylodes, Solanumtuberosum, Capsicum annReum, Brassica oleracea var. virdis, Solanum melongena, Solanum lycopersicum.*	*Avena sativa* (Oats), *Brassica juncea* (ShalimarSarson- 3&2), *Pisum sativum, Allium cepa, Allium sativum, Avena sativa, Raphanus sativus, Brassica rapa, Daucus sativus, Brassica oleracea var. virdis.*
2.	**Hortisilvipasture-System**	*Populus deltoides, Populus nigra, Salix alba, Salix fragilis, Ulmus villosa, Robinia pseudoacacia, Ailanthus altissima,* .	*Malus domestica, Pyrus communis, Prunus armeniaca, Prunus persica, Prunus avium, Punica granatum, Vitus vinifera*	*Trifolium repens, Trifolium pratense, Amaranthus spp, Lolium perennes, Bromus japonicus, Lolium multiflorum, Dactylis glomerata*, *Festuca pretense, Festuca arundinacea*	*Avena sativa* (Sabzar)
3.	**Agrisilviculture-System (Boundary plantation)**	*Populus deltoides, Ulmus villosa, Salix alba, Salix fragilis, Populus balsamifera*	-	*Oryza sativa* (Shalimar Rice-1, Shalimar Rice-2)	*Avena sativa*(Sabzar) *Brassica juncea*(Shalimar sarson-3, Shalimar sarson-2)
4.	**Home gardens**	*Salix fragilis, Populus balsamifera, Ailanthus altissima, Aesculus indica, Morus alba, Populus deltoides, Ulmus villosa, Salix alba, Robinia pseudoacacia*	*Punica granatum, Malus domestica, Pyrus communis, vitus vinifera, Prunus domestica, Prunus avium, Prunus persica, juglans regia*	*Zea mays, Phaseolus vulgaris, Brassica oleracea var. botrytis, Brassica oleracea var.capitata, Brassica oleracea var. viridis, Solanummelongena, Solanum lycopersicum, Capsicum annum, Cucurbita pepo, Lagenaria Siceraria*	*Pisum sativum, Allium cepa, Allium sativum, Raphanus sativus, Brassica rapa, Daucus sativus and Brassica oleracea var.virdis*

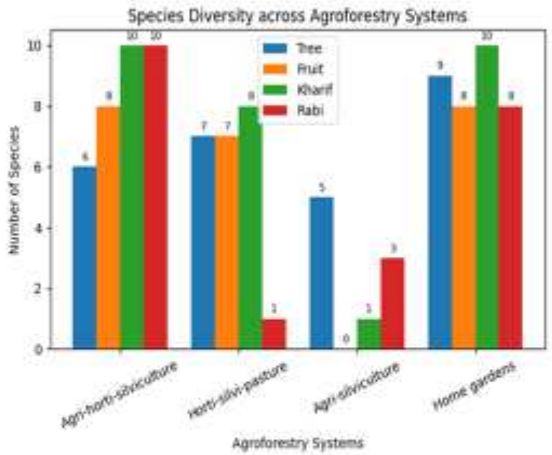


Fig 2

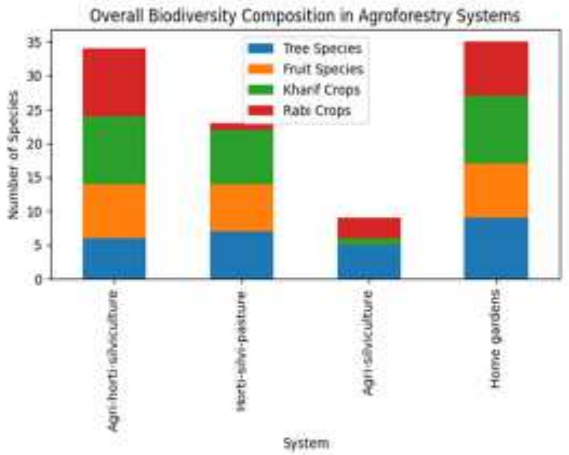


Fig 3

Area under Agroforestry systems

Table 2, presents the adoption pattern and land allocation of prominent agroforestry systems among the sampled households (n = 112) in district Ganderbal. The data indicate that while homegardens were adopted by the largest number of households (30.36%), they covered a relatively smaller area (11.86%), consistent with previous research showing that homegarden systems are widely adopted but occupy limited land due to their household-oriented scale and multilayer crop integration (Kumar and Kunhamu, 2022). The boundary plantation (agrisilviculture) system was adopted by 25% of households, occupying 25.14% of the total agroforestry area. Similar patterns have been observed in other Indian studies, where boundary and mixed plantation systems tend to be preferred by farmers with limited cultivable land because they integrate woody perennials without reducing cash crop area (Sharma *et al.,* 2020). The agrihortisilviculture system was practiced by 24.11% of households and accounted for 28.32% of the total area. This reflects a trend observed in diverse agroecological regions of India, where complex systems combining trees, horticultural crops, and annual crops are significant for livelihood diversification and resource optimization (Berry *et al.,* 2023). Interestingly, the hortisilvipasture system, though showing the lowest adoption rate (20.53%), covered 30% of total area. Such

systems generally require larger tracts for integrating tree, forage, and pasture components, which is a typical land allocation trade-off reported in Himalayan and sub-tropical agroforestry surveys (Punam *et al.,* 2020). Overall, the contrasting pattern between household adoption and area coverage observed in this study, where smaller systems like homegardens have high adoption but low land share, and larger systems like hortisilvipasture have low adoption but high area share aligns with broader observations from (Sharma *et al.,* 2020). Differences in landholding size, livelihood objectives, and resource constraints strongly influence both adoption intensity and area allocation across agroforestry types.

Table 2: Description of Prominent agroforestry systems

S. No.	Agroforestry types	Households Adopting	Area in Hectares
1.	Homegardens	34 (30.36)	3.36 (11.86)
2.	Agrisilviculture system (Boundary Plantation)	28 (25)	7.12 (25.14)
3.	Agrihortisilviculture system	27 (24.11)	9.38 (28.32)
4.	Hortisilvipasture system	23 (20.53)	8.46 (30)
	Total	**112**	**28.32**

Figures in the parenthesis indicate percentages

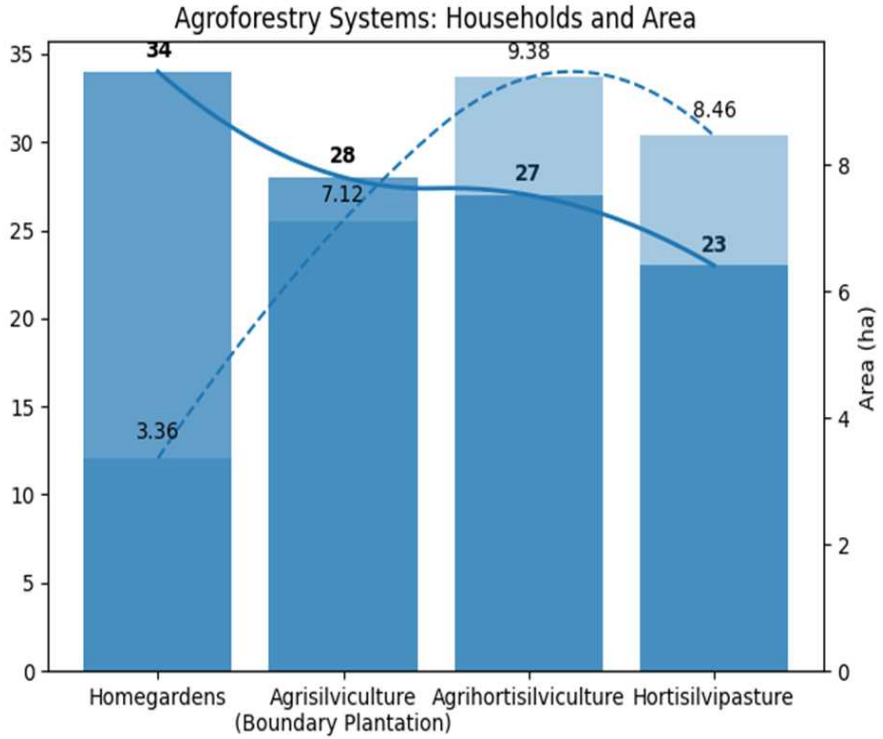


Fig. 4

Cropping Intensity

The cropping intensity and distribution of agricultural crops under the prominent agroforestry systems are presented in Table 3. The data indicate that a variety of cereal, pulse, vegetable, forage, and oilseed crops are cultivated across different agroforestry systems during the kharif and rabi seasons, along with perennial components such as orchards and plantations. Among the kharif crops, the major cereals recorded were *Oryza sativa* (Shalimar Rice-1 and Shalimar Rice-2) and *Zea mays*. These cereals were primarily cultivated under the agrisilviculture system (boundary plantation), where they occupied 44.20% of the cropped area, while cereals were absent in homegarden and hortisilvipasture systems. Pulses such as *Vigna radiata*, *Glycine max,* and *Phaseolus vulgaris*

were mainly observed under homegarden (8.24%) and agrihortisilviculture systems (9.96%), with an overall mean area of 0.51ha.Vegetable crops including *Brassica oleracea* varieties, *Solanum melongena*, *Solanum lycopersicum*, *Capsicum annuum*, *Cucurbita pepo*, *Lagenaria siceraria*, and *Solanum tuberosum* were largely concentrated in homegarden systems, where they occupied 30.90% of the cropped area, followed by agrihortisilviculture systems (9.44%), with an overall mean area of 0.84 ha. Forage crops such as *Trifolium repens, Trifolium pratense, Amaranthus spp., Lolium perenne, Bromus japonicus, Lolium multiflorum, Dactylis glomerata, Festuca pratensis*, and *Festuca arundinacea* were widely cultivated, particularly under the hortisilvipasture system, where they occupied 24.70% of the area, followed by agrihortisilviculture (8.46%) and homegardens (7.61%), with an overall mean of 1.33 ha. Fallow land during the kharif season was mainly recorded under hortisilvipasture systems (10.32%) and agrihortisilviculture systems (1.84%).

During the rabi season, oilseed crops such as *Brassica juncea* (Shalimar Sarson-2 and Shalimar Sarson-3) were cultivated mainly in agrihortisilviculture and agrisilviculture systems, occupying 17.18% and 27.50% of the area, respectively, with an overall mean of 1.53 ha. Vegetable crops including *Pisum sativum, Allium cepa, Allium sativum, Raphanus sativus, Brassica rapa, Daucus carota,* and *Brassica oleracea* var. viridis were predominantly grown in homegardens, accounting for 31.22% of the cropped area, followed by agrihortisilviculture systems (6.68%). Forage crops such as *Avena sativa* (Sabzar varieties) were distributed across different systems, with the highest proportion observed under agrisilviculture (18.10%), followed by hortisilvipasture (13.81%) and agrihortisilviculture systems (10.36%). Perennial components also contributed significantly to the agroforestry systems. Fruit orchards were mainly associated with agrihortisilviculture systems (18.29%) and hortisilvipasture systems (16.12%), with an overall mean area of 1.27 ha. Similarly, agroforestry plantations were recorded across all systems, with the highest proportion under agrisilviculture systems (11.60%), followed by hortisilvipasture (7.88%), homegardens (6.49%), and agrihortisilviculture systems (4.72%). The gross cropped area varied among the agroforestry systems, ranging from 6.31 ha in homegardens to 15.25 ha in agrihortisilviculture systems, with an overall mean of 12.16 ha. The cropping intensity under different agroforestry systems showed considerable variation. The highest cropping intensity was recorded in agrisilviculture systems (179.21%), followed by homegardens (173.83%), hortisilvipasture systems (169.38%), and agrihortisilviculture systems (162.58%), with an overall cropping intensity of 171.75%. This indicates efficient utilization of land resources through the integration of annual crops with perennial tree components in the agroforestry systems of the study area. Higher cropping intensity observed in agroforestry systems, particularly in

homegardens, may be explained by the fact that homegardens function as an important land-use system primarily aimed at agricultural production and ensuring household food security. Farmers tend to cultivate a wide range of crops during both the kharif and rabi seasons, while tree components are maintained at relatively lower densities. As a result, an increase in cropping intensity often corresponds with reduced emphasis on forest-based production within homegarden systems. Similar observations were documented by Anjum (2017) in Budgam district of Jammu and Kashmir. Likewise, Sood (2006) reported that higher cropping intensities generally limit the available space for the cultivation of woody perennials, and the degree of agroforestry adoption does not show significant variation with increasing cropping intensity. Dahiya *et al.,* 2022, also demonstrates that agroforestry systems significantly influence crop yield, nutrient uptake, and cropping patterns, emphasizing the role of integrated land-use systems in improving agricultural productivity.

Table 3: Cropping intensity of agriculture crop species under prominent agroforestry systems

S. No.	Crop type	Crops	Home gardens(ha)	Agri horti silviculture system (ha)	Agri silviculture system (ha)	Horti-silvi-pasture system(ha)	Overall mean (ha)
A	**Kharif**						
1.	Cereals	K_1 & K_2	-	1.34 (8.78)	5.64 (44.20)	-	1.74
2.	Pulses	K_{11}, K_{12}& K_{13}	0.52 (8.24)	1.52 (9.96)	-	-	0.51
3.	Vegetables	K_3, K_4, K_5, K_6, K_7, K_8, K_9, K_{10}, K_{14}	1.95 (30.90)	1.44 (9.44)	-	-	0.84
4.	Forage crops	K_{15}, K_{16}, K_{17}, K_{18}, K_{19}, K_{20}, K_{21}, K_{22}, K_{23}	0.48 (7.61)	1.29 (8.46)	-	3.54 (24.70)	1.33
5.	Fallow land	-	-	0.28 (1.84)	-	1.48 (10.32)	0.44
	Subtotal	**-**	**2.95 (87.79)**	**5.87 (62.58)**	**5.64 (79.21)**	**5.02 (59.33)**	**3.61**
B	**Rabi**						
1.	Mustard	R_2	-	2.62 (17.18)	3.51 (27.50)	-	1.53
2.	Pulses	-	-	-	-	-	-
3.	Vegetables	R_3, R_4, R_5, R_6, R_7, R_8 & R_9	1.97 (31.22)	1.02 (6.68)	-	-	2.22
4.	Forage crops	R_1	--	1.58 (10.36)	2.13 (18.10)	1.98 (13.81)	1.42
5.	Fallow land	-	0.98 (15.53)	0.65 (4.26)	-	3.04 (21.21)	1.17
	Subtotal	**-**	**2.95 (87.79)**	**5.87 (62.58)**	**5.64(79.21)**	**5.02 (59.33)**	**4.87**
C	**Perennial crops**						
1.	Orchards	**-**	-	2.79 (18.29)	**-**	2.31 (16.12)	1.27
2.	Plantations		0.41 (6.49)	0.72 (4.72)	1.48 (11.60)	1.13 (7.88)	0.935
	Subtotal		**0.41 (12.20)**	**3.51 (37.42)**	**1.48 (20.78)**	**3.44 (40.66**	**2.21**
Gross cropped area (ha)			6.31 (100)	15.25 (100)	12.76 (100)	14.33 (100)	12.16
Cropping intensity (%)			**173.83**	**162.58**	**179.21**	**169.38**	**171.75**

Figures in the parentheses indicate percentages

(**Kharif crops:** K_1*Oryzasativa* (ShalimarRice-1, ShalimarRice-2), K_2 *Zea mays,* K_3 *Brassica oleracea var. botrytis,* K_4 *Brassica oleracea var.capitata,* K_5*Brassica oleracea var. viridis,* K_6 *Solanum melongena,* K_7 *Solanum lycopersicum,* K_8 *Capsicum annum,* K_9 *Cucurbita pepo,* K_{10} *Lagenaria siceraria,* K_{11} *Vigna radiata,* K_{12} *Glycine max,* K_{13} *Phaseolus vulgaris,* K_{14} *Solanum tuberosum.* K_{15} *Trifolium repens,* K_{16} *Trifolium pratense,* K_{17} *Amaranthus spp,* K_{18} *Lolium perennis,* K_{19} *Bromus japonicus,* K_{20} *Lolium multiflorum,* K_{21} *Dactylis glomerata*, K_{22}*Festuca pretense* andK_{23} *Festuca arundinacea* **Rabi crops:** R_1 *Avena sativa*(Sabzar, SKO-90, SKO-20, SKO-96) and R_2*Brassica juncea*(Shalimar sarson 3, Shalimar sarson 2), R_3 *Pisum sativum,* R_4 *Allium cepa,* R_5 *Allium sativum,* R_6 *Raphanus sativus,* R_7*Brassica rapa,* R_8 *Daucus sativus and* R_9 *Brassica oleracea var.virdi*

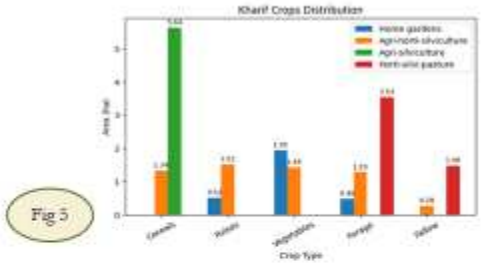


Fig 5

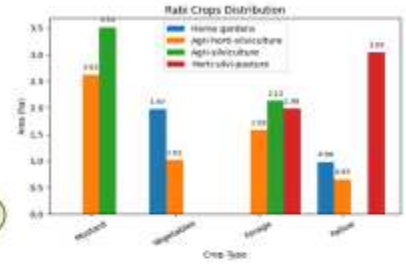


Fig 6

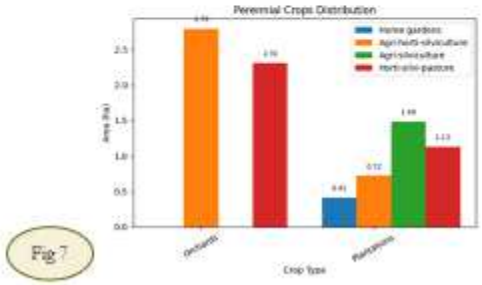


Fig 7

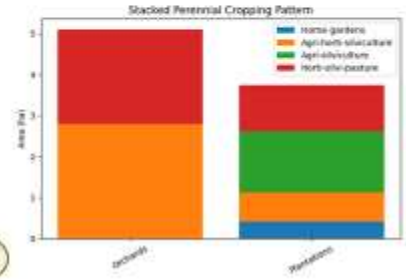


Fig 8

Edaphic Characteristics of Prominent Agroforestry Systems

The soil properties varied significantly among the agroforestry systems and between soil depths (Table 4). Soil pH increased with depth across all systems, while EC, organic carbon (OC), available N, P and K decreased from surface (0-30 cm) to subsurface (30-60 cm) soils. Similar depth-wise variations have been reported in agroforestry systems due to greater accumulation of organic residues and nutrient cycling in surface horizons (Das, 2024). The Home Garden system recorded significantly higher OC (1.92 and 1.02%), available N (329.21 and 285.29 kg ha^{-1}), P (39.11 and 34.79 kg ha^{-1}) and K (298.73 and 269.99 kg ha^{-1}) than other agroforestry systems at both depths. The enhanced fertility status may be attributed to continuous litter deposition, greater biomass

production and efficient nutrient recycling associated with diversified vegetation structure. Similar findings were reported by Sharma *et al.* (2022), who highlighted the role of homegarden agroforestry systems in improving soil quality and nutrient availability. The significantly higher organic carbon under Home Garden and Agri-horti-silviculture systems indicates greater carbon sequestration potential through litter inputs and root turnover. Agroforestry systems have been widely recognized for enhancing soil organic carbon stocks and improving soil health compared with less diversified land-use systems (Parmar *et al.,* 2022).The decline in OC and nutrient concentrations with increasing soil depth observed in the present study reflects reduced organic matter accumulation and biological activity in subsurface layers. Overall, soil fertility followed the order Home Garden > Agri-horti-silviculture > Horti-silvi-pasture > Boundary Plantation, highlighting the positive influence of diversified agroforestry systems on soil quality and nutrient dynamics.

Table 4. Soil Properties of Prominent Agroforestry Systems of District Ganderbal at two depth (0-30 cm and 30-60 cm)

Systems	pH (0-30 cm)	pH (30-60 cm)	EC (dS m^{-1}) (0-30 cm)	EC (dS m^{-1}) (30-60 cm)	OC (%) (0-30 cm)	OC (%) (30-60 cm)	N (kg/h) (0-30 cm)	N(kg/h) (30-60 cm)	P(kg/h) (0-30 cm)	P(kg/h) (30-60 cm)	K (kg/h) (0-30 cm)	K (kg/h) (30-60 cm)
Home Garden	6.72 ± 0.01	6.82 ± 0.02	0.39 ± 0.02	0.28 ± 0.02	1.92 ± 0.02	1.02 ± 0.010.	329.21 ± 0.54	285.29 ± 0.54	39.11 ± 0.74	34.79 ± 0.44	298.73 ± 0.91	269.99 ± 0.61
Agri-horti-silviculture	6.74 ± 0.03	6.92 ± 0.05	0.37 ± 0.03	0.26 ± 0.01	1.73 ± 0.02	0.97 ± 0.01	321.40 ± 0.47	284.32 ± 0.71	38.83 ± 0.42	29.93 ± 0.63	274.17 ± 0.94	267.49 ± 0.43
Horti-silvi-pasture	6.82 ± 0.02	7.01 ± 0.04	0.34 ± 0.02	0.24 ± 0.02	1.15 ± 0.03	0.91 ± 0.01	299.60 ± 0.98	276.83 ± 2.18	37.22 ± 0.70	30.87 ± 0.53	269.17 ± 0.92	252.31 ± 0.75
Boundary Plantation	7.04 ± 0.03	7.14 ± 0.03	0.32 ± 0.02	0.22 ± 0.01	0.96 ± 0.02	0.65 ± 0.02	298.31 ± 0.81	270.43 ± 0.87	29.10 ± 0.54	26.16 ± 1.19	240.90 ± 0.86	225.77 ± 0.73
CD (5%)	0.044	0.055	0.026	0.026	0.036	0.013	0.457	1.645	0.528	1.285	0.757	0.717
p-value	1.67×10^{-7}	2.29×10^{-6}	0.00081	0.00264	1.31×10^{-12}	1.20×10^{-12}	$< 2 \times 10^{-16}$	2.17×10^{-8}	2.81×10^{-11}	9.26×10^{-7}	3.53×10^{-16}	8.82×10^{-16}
Sig	***	***	***	**	***	***	***	***	***	***	***	***

Conclusion

The present study demonstrated that agroforestry systems in District Ganderbal are diverse and play a significant role in supporting rural livelihoods, enhancing land-use efficiency, and improving soil fertility. Four prominent agroforestry systems, namely Homegarden, Agrihortisilviculture, Hortisilvipasture, and Agrisilviculture (boundary plantation), were identified, each characterized by distinct combinations of tree, fruit, crop, and forage components. While Homegarden was the most widely adopted system, Hortisilvipasture occupied the largest share of agroforestry area, indicating differences in farmers' resource availability and production objectives. The integration of annual crops with woody perennials resulted in high cropping intensities across all systems, reflecting efficient utilization of available land resources. Among the systems studied, Agrisilviculture recorded the highest cropping intensity, whereas Homegarden systems exhibited the greatest species diversity and multifunctionality. Significant variations in soil properties were observed among agroforestry systems and soil depths. Homegarden and Agrihortisilviculture systems maintained comparatively higher organic carbon content and greater availability of nitrogen, phosphorus, and potassium, highlighting their positive contribution to soil quality through enhanced litter deposition, biomass production, and nutrient recycling. Overall, the study confirms that diversified agroforestry systems contribute substantially to sustainable agricultural production, soil fertility enhancement, and livelihood security in the Kashmir Himalaya. Promoting species-rich systems such as Homegarden and Agrihortisilviculture, along with suitable policy support, extension services, and farmer awareness programmes, can further strengthen the ecological and economic benefits of agroforestry. These systems offer a viable pathway for sustainable land management, climate resilience, and long-term agricultural sustainability in the region.

Acknowledgement

The authors want to convey heartfelt appreciation to the Department of Silviculture and Agroforestry, SKUAST -K for offering an excellent educational setting and improved resources that enabled to successfully conduct research and expand understanding.

Declaration

Ethics approval and consent to participate

This research does not contain any studies that include human population or animals

Consent of Publish

Informed consent was obtained from all individual participants included in the study.

Availability of data and material

The data will be provided on a reasonable request, if required and the corresponding author will provide the data.

Competing interests

On behalf of all authors, the corresponding author states that there is no conflict of interest for this submission.

Funding

The authors did not receive support from any organization for the submitted work.

Author contributions

Sufiya Shabir: Conceived and conducted the research work, carried out field surveys, collected and analyzed data, and prepared the manuscript.

Dr. G. M. Bhat: Served as the principal advisor, provided overall guidance in research planning, methodology, interpretation of results, and manuscript review.

Dr. N. A. Pala: Assisted in data analysis, statistical interpretation, and provided valuable suggestions during the preparation of the study.

Dr. Meghna Rashid: contributed through constructive suggestions, technical inputs, and continuous support throughout the research work

References

Anjum, K. 2017. Diversity, Utilization and Livelihood of Homegarden Forest Resources in Budgam District of Kashmir, M.S.c. Thesis, Faculty of Forestry, SKUAST-K.

Banyal, R., Masoodi, N. A., Masoodi, T. H., Sharma, L. K. and Gangoo, S. A. 2011. Knowledge and attitude of farmers towards agroforestry practices in north Kashmir-a case study. *The Indian Forestry* 137(12): 1377-1381.

Berry, N., Dilraj, I., Dubey, S and Rai, N. 2023. *Prominent agroforestry systems adopted by farmers in Seoni District of Madhya Pradesh. The Indian Forester, 149*(8), 166316.

Bhat, G. M and Islam, M. A. 2019. Productivity and economic evaluation of willow (*Salix alba* L.)-based silvopastoral agroforestry system in Kashmir Valley**.** *Journal of Applied and Natural Science, 11*(3), 743–751.

Bhat, G. M., Shabir, S., Rashid, M., Pala, N. A., Dutt, V., & Fayaz, B. (2023). Growth Dynamics of Pulses and Fruit Trees in Fruit-Based Agroforestry Systems on Degraded Lands of Central Kashmir Himalayas. *Climate Change and Environmental Sustainability*, *11*(2), 67-75.

Dahiya, G., Bhardwaj, K. K., Devi, S., Ahlawat, I., Singh, C and Dhillon, R. S. 2022. Influence of different agroforestry systems on yield and nutrient uptake in semi-arid region of Haryana. *Indian Journal of Agroforestry, 24(2),* 80–87.

Dalrymple, D. G. 1971. Survey of multiple cropping in less developed nations. Foreign Agricultural Economic report. Washington, DC: Economic Research Service.

Das, D. 2024. Impact of Agroforestry on Soil Fertility and Soil Carbon: A Review. *Indian Journal of Agroforestry*, 26(3).

Fayaz, B., Bhat, G. M., Dutt, V., Pala, N. A., Rashid, M and Shabir, S. 2026. Soil Health and Carbon Stock Enhancement through Fruit Tree-based Agroforestry in the Degraded Lands of Central Kashmir Himalayas. *Int J Agric Sc Food Technol*, *12*(1), 001-007.

Islam, M. A., Banyal, R., Rai, R. and Singh, P. K. 2012. Determinant factors of agroforestry adoption in North Kashmir. *Indian Journal of Social Research* 53(2): 123-129.

Islam, M. A., Qaiser, K. N. and Bhat, G. M. 2017(a). Indigenous knowledge in traditional agroforestry systems of Kashmir valley: Current challenges and future opportunities. *International Journal of Forestry and Crop Improvement* 8(1): 68-77.

Jackson, M. L. 1958. Soil Chemical Analysis. Prentice Hall, New Jerse

Jackson, M. L.1973. Soil chemical Analysis (2nd edition). Prentice Hall of India Private Limited, New Delhi, pp 1-498.

Kumar, B and Kunhamu, T. 2022. Agroforestry research methodology with special reference to the biophysical aspects of tropical homegardens. *Indian Journal of Agroforestry, 24*(3).

Kumar, B. M., Singh, A. K. and Dhyani, S. K. 2012. South Asian Agroforestry: traditions, transformations and prospects. In: *Agroforestry-The Future of Global land use* (Eds. B. M. Kumar, A. K. Singh and S. K. Dhyani). Springer, Dordrecht. pp. 359-389.

Mughal, A. H and Bhattacharya, P. K. 2002. Agroforestry systems practiced in Kashmir Valley of Jammu and Kashmir. *Indian Forester, 128*(8), 846–852.

Nair, P. R., Kumar, B. M and Nair, V. D. 2021. *An introduction to agroforestry: four decades of scientific developments* (pp. 1-649). Cham: Springer.

Nair, P. R., Kumar, B. M and Nair, V. D. 2022. Global distribution of agroforestry systems. In *An introduction to agroforestry: four decades of scientific developments* (pp. 45-58). Cham: Springer International Publishing.

Olsen, S. R., Cole, C.V., Watanate, I.S. and Dean, L.A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. US Department of Agriculture, Washington D.C. Circular No.939 pp 125-126.

Parmar, B., Vishwakarma, A., Padbhushan, R. 2022. Hedge and Alder-Based Agroforestry Systems: Potential Interventions to Carbon Sequestration and Better Crop Productivity in Indian Sub-Himalayas. *Frontiers in Environmental Science*, 10, 858948. DOI: 10.3389/fenvs.2022.858948.

Patel, S. K., Sharma, A., Barla, A and Singh, G. S. 2024. Traditional Farming in the Indian Himalayan Region: Preserving Agro-Biodiversity and Future Food Security. *The Resilience of Traditional Knowledge Systems for a Sustainable Future: A Focus on Agriculture and Food Practices in the Himalayas*, 27-57.

Punam, P., Atul and Rameshwar, . 2020. Adoption of traditional agroforestry in Kangra Valley of Himachal Himalayas. *Indian Journal of Agroforestry, 3*(1).

Rao, C. H. H. 2000. Declining Demand for Foodgrains in Rural India: Causes and Implications, *Economic and Political Weekly*22: 201-206.

Ray, G. L. and Mondol, S. 2004. Research Methods in Social Sciences and Extension Education, Kalyani Publishers, New Delhi, 66-76.

Richins, M.L. 1983. Negative Word-of-Mouth by Dissatisfied Consumers: *A Pilot Study. J. Mark* 47, 68–78.

Rizvi, R. H., Vishnu, R., Handa, A. K., Rizvi, J and Rizvi, S. H. 2021. Mapping of agroforestry systems and Salix species in Western Himalayan agroclimatic zone of India. *Current Science, 121*(10), 1347–1351.

Sharma, A., Agarwal, R and Upadhayaya, S. 2020. Exploratory studies on land holding pattern and adoption of agroforestry systems by the farmers in Jabalpur district of Central India. *Indian Journal of Agroforestry, 7*(2).

Sharma, R., Mina, U and Kumar, B.M. 2022. Homegarden agroforestry systems in achievement of Sustainable Development Goals: A review. *Agronomy for Sustainable Development*, 42, 44. DOI: 10.1007/s13593-022-00781-9.

Sood, K. K. 2006. The influence of household economics and farming aspects on adoption of traditional agroforestry in western Himalaya. *Mountain Research and Development* 26(2): 124-130.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the determination of available nitrogen in soils. *Current Science* 25:259-260.

Verma, K., Sharma, P., Bhardwaj, D. R., Singh, M. K., Verma, T and Thakur, P. 2024. Traditional Agroforestry Practices in the Indian Himalayas. In *Learning 'from' and 'with' the Locals: Traditional Knowledge Systems for Environmental Sustainability in the Himalayas* (pp. 135-162). Cham: Springer Nature Switzerland.

Walkley, A and Black, I. A. 1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil science*, *37*(1), 29-38.