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Geometry, Distribution and Regeneration Pattern of Trees in Agroforestry Systems along Altitude and Aspects in the Upper Yamuna Region of Uttarakhand Himalaya, India

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Abstract This study narrates geometry, distribution and regeneration pattern of traditional agroforestry systems viz. Agrisilviculture (AS), Agrisilvihorticulture (ASH) and Agrihorticulture (AH) systems in the Upper Yamuna region of Uttarkashi district in Uttarakhand, India. The study spread in different altitudinal ranges from 1000-1500m, 1500-2000m, 2000-2500m with two aspects (northern and southern) to observe the diversity of agroforestry along altitude and aspects. In this study, tree geometry deals with arrangement and orientation of trees on farm land in different traditional agroforestry systems. It was found that the tree geometry have not shown particular pattern in location of trees occurring on agriculture field. The positions of trees depended on the nature (forest tree/ fruit tree), use of tree species, origin of occurrence (naturally grown/planted), nature of field crop and interaction with the intercrops (positive/negative interactive effect). The maximum numbers of trees were recorded on bunds followed by other places and on middle of agricultural field in AS system. In AH system the more number of trees was recorded on middle followed by other places and on bund whereas no regular pattern of tree geometry was recorded in ASH system. In diversity studies, the number of tree species ranged from 7 to 13, 4 to 16 and 1 to 8 in AS, ASH and AH respectively. The tree diversity recorded to be highest in ASH and lowest in AH, however higher number of tree species recorded in lower elevation compared to higher. The regeneration status dealt with presence of trees, saplings and seedlings under different traditional agroforestry systems. The minimum number of seedling and sapling were observed in AH followed by AS and ASH. With respect to elevation, comparatively higher numbers of seedlings and saplings presence were recorded in 1000-1500m and minimal presence in 2000-2500m inferred poor regeneration in higher elevation. Similarly seedlings and saplings presence is recorded lower in southern aspect compared to northern aspect. The tree structure in AS and AH systems recorded more number of trees under 20-30 cm diameter class and ASH in 10-20 diameter class, similarly more trees were recorded in AS, AH under 10-15m height class and ASH under 5-10m height class. The overall representation of trees in above mentioned agroforestry systems recorded reciprocal relationship i.e. higher number in lower elevation (1000-1500m) and lower in higher elevation (2000-2500m).

Keywords: *tree geometry, orientation, diversity, traditional agroforestry, altitude, aspect, diameter class, height class, regeneration pattern*

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1. Introduction

Traditional agroforestry practices have been a part of agricultural practices in the Uttarakhand, Himalaya of India since time immemorial. Protecting and growing Multipurpose Trees (MPTs) on the farm bund for the multifunctional uses is common practice by the farmers of this region. Change in tree species, composition and agricultural crops (in agroforestry systems) along the altitude and aspect are interesting and more pertinent areas to be studied. The elevation of landscape is a base for understanding the relationship between climate and vegetation in mountainous areas [34]. Two common forms of traditional agroforestry practiced in hills of Uttarakhand are simultaneous agroforestry involving substantial input of manure derived from forest litter and animal excreta practiced on terraced slopes in private land and sequential agroforestry system involving slash-burn practice and cultivation on un-terraced slopes without tillage and

manuring [20]. The vegetation of varying topography of the region changes its diversity, composition and structure along altitudinal gradient. The geographic and climatic conditions change sharply along the altitude [15], however the elevation beyond 2000 m asl may accumulate snow and persist cold temperature during winter [38]. This change in hilly terrains (elevation) also leads to change in composition of tree-crop combinations in agri-silvi-horticulture systems which are important to be documented [3]. The track of the sun (aspect) in the hilly landscape also plays significant role in the vegetation and land use pattern [3]. Hilly ecosystems around the globe have distinct floral and faunal communities and high level of diversity due to the variation in climatic conditions [10]. Though the studies on change of vegetation along altitudinal gradient have been conducted by many scientists in the Garhwal Himalayan region [1,28] but the present study particularly focuses on geometry, orientation, distribution, and regeneration pattern of trees in traditional Agroforestry systems in Upper Yamuna region of Uttarakhand Himalaya, India.

2. Materials and Methods

The present study was carried in the Upper Yamuna forest villages in Uttarakashi district of Uttarakhand Himalaya, India during 2012-13. Three altitudes 1000 to 1500m (E1), 1500 to 2000m (E2) and 2000 to 2500m (E3) asl covering Northern (N) and Southern (S) aspects comprising six study sites (E1N, E1S, E2N, E2S, E3N, E3S) in Agrisilviculture (AS), Agrisilvihorticulture (ASH) and Agrihorticulture (AH) systems spreading in Latitude 30° 43’ to 30° 73’N and Longitude 78° 27’ to 78° 45’E (Figure 1).

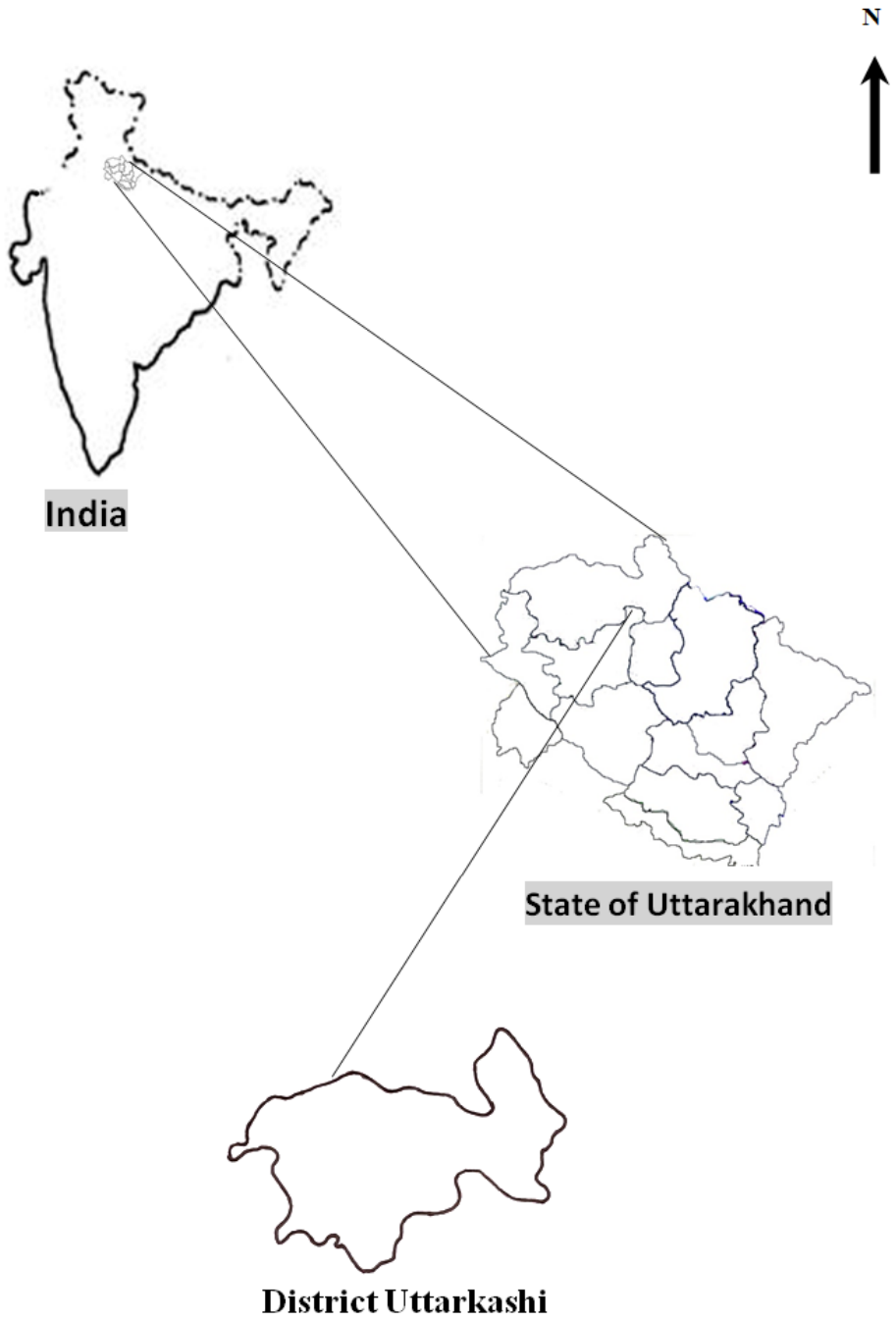

Figure 1. Location Map of the Study Area

Sampling plots of 10 X 10 m were selected in the varying altitudinal ranges to study the geometry, distribution, regeneration and Tree-crop combination in traditionally existing agroforestry systems. The stratified random sampling approach was adopted in each selected site. In his method the area was divided into different strata and the random samples were taken from each strata. The high Himalayan region of the study area was covered with snow cap during winter season. Rainfall is highly variable and largely depends upon the altitude. The major tree species in the area are *Chir pine* in the lower elevation and *Devdar*, *Fir* and various *Quercus* species on the higher elevation, beyond this the alpine pastures are found. The orientation of trees on the agroforestry systems (tree geometry) was measured on the basis of data on trees collected from three positions on the existing agroforestry systems *viz.* bunds, middle and other portion of the agriculture fields along altitude and aspects.

To study the regeneration pattern in existing agroforestry systems, the seedling, sapling and trees of different tree species were studied which distinguished the different stages of the plants following Khanna, 1996. The regeneration status of tree species in a forest is considered as "good" when seedling density > sapling density > adult tree density; "fair" when seedling density > sapling density ≤ adult density; "poor", when the species survived in only the sapling stage but not in the seedling stage; "none", for species with no sapling or seedling stages but present as adult trees, and "new" when adults of a species were absent but sapling and/or seedling stage(s) were present [13,33]. The plant diversity (Shannon Index) in different layers of each agroforestry system was quantified as per Shannon & Wiener [29], Concentration of dominance (Simpson Index) by Simpson [31], Equitability (e) was calculated as suggested by Pielou [23], Species richness was calculated following Margalef equation [17] and Beta diversity was calculated as per Whittaker [40,41]. The trees present in the agroforestry systems were divided into different diameter and height classes. The diameter classes used for trees were at 10 cm interval (0-10, 10-20 to 70-80 cm), while height classes used for trees were at 5m interval (0-5, 5-10 to 25-30m). The number of trees falling in each diameter class was recorded and density of trees was calculated on the basis of diameter and height class in different altitude and aspect.

3. Results and Discussion

3.1. Tree Geometry (Position/orientation of trees) in Traditional Agroforestry Systems

The results on tree geometry in different traditional agroforestry systems have shown no definite pattern in orientation of trees on agriculture field. The position of trees depend on the nature (forest tree/ fruit tree), uses of tree species, origin of occurrence (naturally grown/planted), nature of the field crops (shade loving crop, light demanding crop) and interaction with the intercrops (positive/negative interactive effect).

In traditional agroforestry systems there was no uniformity in the orientation or positional arrangement of trees on fields. Forest tree species were generally present on bunds whereas the fruit tree species on middles portion of agricultural field. In agrisilviculture (AS) system, the presence of trees on bunds ranged from 46.70 per cent (site- E1S) to 62.50 (site E2S). The values for category of other places ranged from 23.80 per cent (site- E2S) to 35.60 percent (site-E1S). The lowest value was observed on middle places between 13.80 percent (site-E3N, E2S and E1N) to 17.80 per cent (site E1S) referred in Table 1 and Figure 2a, Figure 2b, Figure 2c.

Table 1. Spatial Tree geometry in different traditional agroforestry systems

AFS/Site	Number of Forest trees per ha			Number of Horticultural trees per ha		
	Bunds	Middle	Other places	Bunds	Middle	Other places
AgriSilviculture System (AS)						
E1N	441.00(60.00)	101.06 (13.80)	192.94 (26.30)	-	-	-
E1S	310.33(46.70)	118.22 (17.80)	236.44 (35.60)	-	-	-
E2N	292.13(51.30)	99.75 (17.50)	178.13 (31.30)	-	-	-
E2S	284.38(62.50)	62.56 (13.80)	108.06 (23.80)	-	-	-
E3N	244.69(56.30)	59.81 1(13.80)	130.50 (30.00)	-	-	-
E3S	181.94(51.30)	53.25 (15.00)	119.81 (33.80)	-	-	-
Agrisilvihorticulture System (ASH)						
E1N	278.44(28.10)	92.81 (9.40)	123.75 (12.50)	40.60 (8.10)	134.38 (26.90)	75.00 (15.00)
E1S	285.47(32.80)	57.09 (6.60)	92.44 (10.60)	25.30 (4.70)	168.75 (31.30)	78.98 (14.60)
E2N	338.29(36.40)	51.15 (5.50)	75.56 (8.10)	17.80 (4.90)	101.48 (28.20)	60.75 (16.90)
E2S	275.58(37.80)	23.73 (3.3)	65.70 (9.00)	3.75 (1.50)	81.25 (32.50)	42.19 (16.90)
E3N	283.50(39.4)	27.00 (3.80)	49.50 (6.90)	6.77 (3.60)	64.48 (33.90)	23.75 (12.50)
E3S	221.25(36.90)	26.25 (4.40)	52.50 (8.80)	9.75 (7.50)	38.19 (29.40)	17.06 (13.1)
Agrihorticulture System (AH)						
E1N	-	-	-	105.20(21.30)	247.50 (50.00)	142.30(28.80)
E1S	-	-	-	63.20 (16.00)	228.10(57.80)	103.70(26.30)
E2N	-	-	-	63.50 (15.90)	250.00 (62.50)	86.50 (21.60)
E2S	-	-	-	84.40 (28.00)	120.00(40.00)	95.40 (32.00)
E3N	-	-	-	34.70 (18.80)	94.81(51.300)	55.50 (30.00)
E3S	-	-	-	16.90 (12.50)	74.30 (55.00)	43.90(32.50)

*Numeric value in parenthesis shows % value.

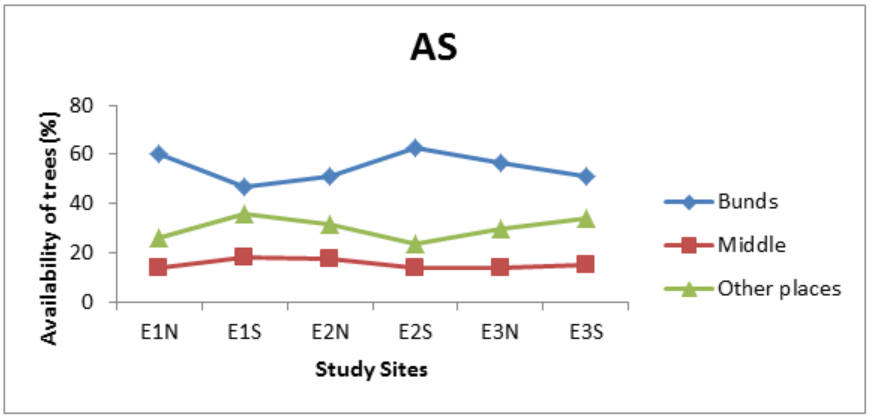

Figure 2a. Spatial Tree geometry in AS system

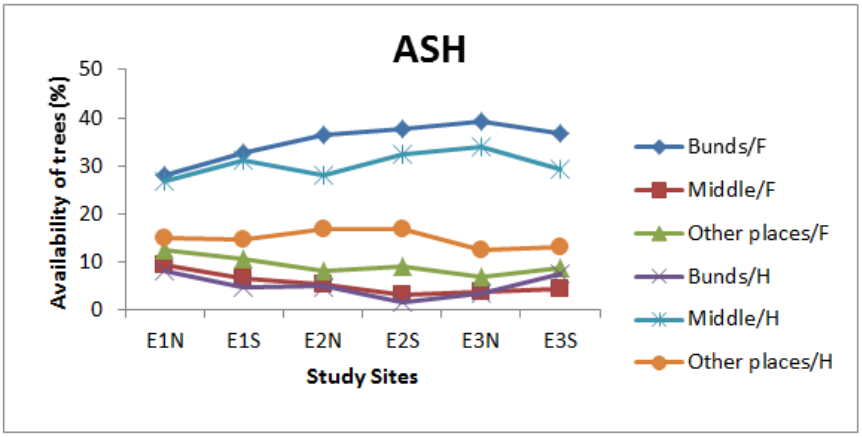

Figure 2b. Spatial Tree geometry in ASH system

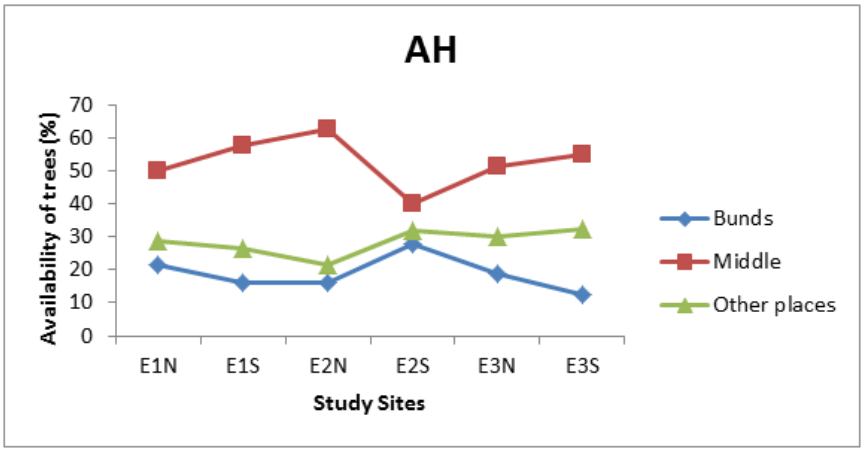

Figure 2c. Spatial Tree geometry in AH system

In agrisilvihorticulture (ASH) system in bunds distribution of forest trees ranged from 28.10 per cent (site- E1N) to 39.40 per cent (site-E3N) while position of fruit tree species on bunds ranged from 1.50 per cent to 8.10 per cent for site E2S and E1N. In middle of the fields, forest trees were present less in numbers than the fruit tree species. The highest distribution value of fruit tree species on middles portion was found 33.90 per cent in site E3N.

In the agrihorticulture (AH) system, 12.50 to 28.00 % fruit trees were present on the bunds, 40.00 to 62.50 % trees were present in middle and 21.60 to 32.50 % on the other places. In this agroforestry system among all the sites maximum fruit tree species (62.50 %) were present on the middles of the site E2N and minimum tree species (12.50 %) were present on bunds of the site E3S. Position of trees (tree geometry) in different traditional agroforestry systems in district Uttarkashi is given in Table 1 and Figure 2a, Figure 2b, Figure 2c.

The tree geometry varied according to the species, purpose, farming system and nature of tree species. The position of trees was also dependent on method of regeneration (natural or artificial). In the traditional agroforestry systems, the forest trees were generally retained on the bunds to minimize the tree-crop interaction as well as for ease in performing cultural operations. The fruit trees were planted in a systematic way in the orchards; because the main objectives were to produce fruits with some shade loving field crops e.g. tuber vegetables (*Solanum tuberosum*, *Raphanus sativus*, *Colocasia*

antiquorum, *Daucus carota*, etc). The density of fruit trees was also higher in the orchards to increase the fruit yield.

In the study carried out by Thakur *et al.*, [36] in agrisilviculture system where the trees were recorded only on the bunds with a total density of (1000 trees/ha), which was low as compared to silvipastoral (2999 trees/ha) and hortisilvipastural (2433 trees/ha) systems, where trees were grown on the entire fields. The Multipurpose trees and shrubs were generally retained by the hill farmers along the field boundaries, because of small land holding, and to avoid difficulties during cultural operations [35]. The numbers of trees on field boundaries were dependent upon the soil, temperature, rainfall and edaphic conditions. The number of trees decreased with an increase in elevation and subsequent decrease in temperature. Tewari [35] has revealed that there was an inverse relationship between altitude and number of trees per hectare and the trend was 87 trees in 500-1000 m elevation to 17 trees above 2000 m.

Hymavathi et al [12] in field survey analysed five main multiple plantation patterns of agroforestry systems which includes 2 to 6 plant species to make 30 different crop geometries (CGs). In each pattern, there were several types of CGs mainly categorized on the basis of number of plant species grown in the central part of the agricultural field (1, 2, 3 or 4 species). All these types were usually followed by the farmers as per the local need, market demand of their product and financial gain to the farmers. Varadaranganatha and Madiwalar [37] In Uttar Kanara districts reported six prominent agroforestry systems practiced in the three distinct agroecological situations (lower elevation area, higher elevation area and coastal area) and In all the area bund planting (21.66 to 36.67 %) was the most prominent agroforestry practiced by farmers, followed by horti-silviculture system (3.33 to 23.33 %) and less prominent practice was block plantation (5.0 to 11.66 %).

3.2. Tree Diversity

The diversity of trees in each agroforestry system on different aspect and elevation (sites) are presented in Table 2, Table 3 and Figure 3. The number of tree ranged from 7 (site-E3S) to 13 (site-E1S) in agrisilviculture system, 4 (site-E3S) to 16 (sites-E2N) in agrisilvihorticulture system and 1 (site-E3S) to 8 (sites-E2N) in agrihorticulture system (Table 2). The reason for the availability of maximum trees species in ASH system includes the occurrence of both forest and horticultural tree species in the system. The mixing of forest tree species was also practiced in fruit orchards by the farmers which were put under proper management as gap filling in the orchards and thus there was more number of tree species in agrisilvihorticultural systems. The Shannon index values were found to be highest on the sites- E2N-ASH and lowest on the site-E3S-AH. The highest Simpson index value was found in site-E3S-AH and lowest in two sites as site-E1S-AS and site- E2N-ASH respectively. The species richness values in different agroforestry systems ranged from 0.00 to 1.90. Site- E2N-ASH has shown highest species richness followed by site- E2S-ASH. Among the different agroforestry systems, the highest equitability (0.43) was observed for site-E3N-ASH and lowest (0.00) on site- E3S-AH. Beta diversity was highest (11.00) on site- E3S-AH while it was lowest on sites- E2N-AH (Table 3). Generalized observation shows reciprocal relationship between elevation and tree diversity i.e. the higher tree diversity in lower elevation and vice verse. Further northern aspect observed more diverse compared to southern aspect. Nautiyal et al, [20] also reported in simultaneous system of agroforestry nine species with total average density of 390 trees ha^{-1}, *Grewia optiva* and *Boehmeria rugulosa* being the most dominant in mid hills of Uttarakhand.

Table 2. Average tree density ($100m^{-2}$) in different agroforestry systems

AF system	E1N	E1S	E2N	E2N	E3N	E3S	**Mean**
AS	10.0	13.0	11.0	11.0	11.0	7.0	10.5
ASH	13.0	14.0	16.0	14.0	8.0	4.0	11.5
AH	5.0	3.0	8.0	5.0	2.0	1.0	3.5
Mean	9.3	10.0	11.7	10.0	7.0	4.0	8.7

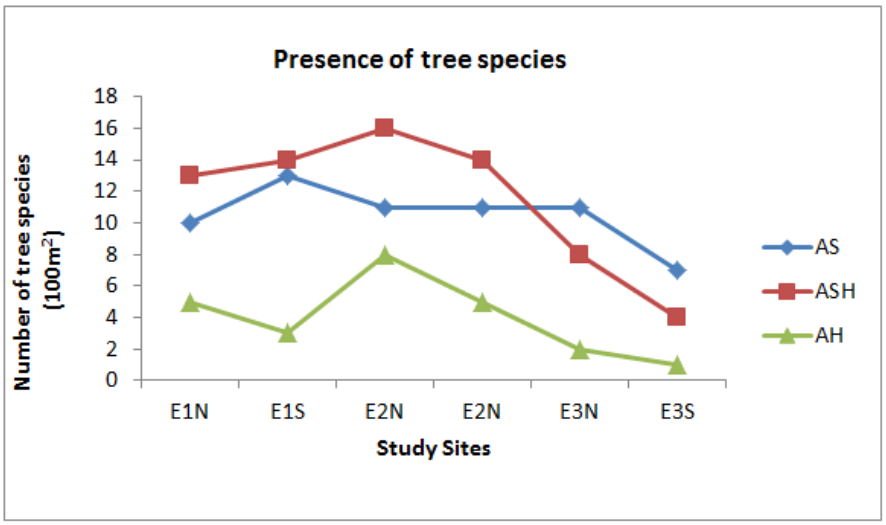

Figure 3. Number of tree species in agroforestry systems

Table 3. Tree diversity indices in different traditional Agroforestry systems

Aspect/AF system	Shannon Index	Simpson Index	Richness	Equitability	Beta Diversity
Agrisilviculture System (AS)					
E1N-AS	0.95	0.13	1.14	0.41	2.40
E1S-AS	1.10	0.08	1.52	0.49	1.80
E2N-AS	1.01	0.11	1.26	0.42	2.20
E2S-AS	0.93	0.14	1.27	0.39	2.20
E3N-AS	0.99	0.11	1.26	0.42	2.20
E3S-AS	0.82	0.16	0.78	0.42	3.40
Agrisilvihorticulture System (ASH)					
E1N-ASH	1.01	0.10	1.50	0.41	2.20
E1S-ASH	1.09	0.09	1.64	0.38	2.00
E2N-ASH	1.11	0.08	1.90	0.39	1.80
E2S-ASH	1.08	0.09	1.68	0.41	2.00
E3N-ASH	0.90	0.13	0.89	0.43	3.50
E3S-ASH	0.58	0.27	0.38	0.42	7.00
Agrihorticulture System (AH)					
E1N-AH	0.63	0.25	0.53	0.39	2.20
E1S-AH	0.47	0.35	0.27	0.42	3.70
E2N-AH	0.73	0.24	0.94	0.35	1.40
E2S-AH	0.67	0.23	0.56	0.42	2.20
E3N-AH	0.30	0.50	0.15	0.43	5.50
E3S-AH	0.00	1.00	0.00	0.00	11.0

AS = Agrisilviculture, ASH = Agrisilvihorticulture, AH = Agrihorticulture system,
E_1= Elevation 1 (1000-1500m), E_2= Elevation 2 (1500-2000m), E_3= Elevation 3= (2000-2500m)
N = Northern aspect, S = Southern aspect.

The diversity indices of these agroforestry systems are comparable with the those reported by different workers for other regions [4,19]. Thakur *et al.* [36] in a similar study in Western Himalaya, reported that among all the three agroforestry systems (AS, SP, HSP), HSP system was more diversified, as it had as many as 12 trees, 4 shrubs, 7 herbs and 6 fruit species. Similar results had also been reported by Toky *et al.* (1989). The Shannon index values of different agroforestry systems in this study was comparatively lower than natural forest; the low diversity values under the present investigation were attributed to limited number of tress (forest and horticulture) retained or planted by the farmers on their farm land as per requirement. The comparatively higher diversity values on northern aspects may be due to the higher moisture content and low insulation rates as compared to southern aspects, which receive the sun rays in later part of the day, when the atmosphere is sufficiently warmed. The effect of aspect on structure and diversity of vegetation was also quantified by several workers [3,26,30,32]. Farmers control tree species' densities and presence (diversity) on farms depending on their preferences and individual species uses. The unused or non-preferred trees species are removed while the useful ones are retained. This selective clearing is often done considering the composition of the original tree population, the ecological conditions, the know-how, the requirements of farmers and their socio-economic environment [21]. Elizabeth and Francisco [9] observed that shift from traditional cacao growing systems under diverse and dense tree canopy to lower or no-shade cover leads loss of direct and functional forest ecosystem values in tropics. It's not only tree diversity but also many ethnobotaical plants are reported in traditional agroforestry systems in Kumaon Himalayas [25].

3.3. Regeneration Pattern

The presence of trees, saplings and seedlings under different traditional agroforestry systems are given in Table 4. Maximum availability of trees in agrisilviculture (AS) system were observed in the site E1N (54.55%) followed by the site E1S (52.14%). The availability of saplings ranged (37.50%) in site E3S to (32.14%) in site E1S while the presence of seedlings varied from (8.33%) in E3SAS to (20.00%) in E1N.

Table 4. Presence/Density of seedling, sapling, and trees per 100m^2 (Regeneration pattern) in traditional agroforestry systems

AFS/Site	Trees	Sapling	Seedling
Agrisilviculture System (AS)			
E1N	4.01 (54.55)	1.87 (25.45)	1.54 (20.00)
E1S	3.47 (52.14)	2.14 (32.14)	1.05 (15.71)
E2N	3.17 (55.56)	1.90 (33.33)	0.63 (11.11)
E2S	2.28 (50.00)	1.82 (40.00)	0.46 (10.00)
E3N	2.39 (55.00)	1.53 (35.11)	0.43 (9.89)
E3S	1.92 (54.17)	1.33 (37.50)	0.30 (8.33)
Agrisilvihorticulture System (ASH)			
E1N	4.22 (56.67)	2.24 (30.00)	0.99 (13.33)
E1S	3.83 (54.29)	2.42 (34.29)	0.81 (11.43)
E2N	3.44 (53.33)	2.29 (35.56)	0.72 (11.11)
E2S	2.50 (51.60)	1.91 (39.00)	0.49 (10.00)
E3N	2.28 (50.00)	1.90 (41.67)	0.38 (8.33)
E3S	1.64 (45.00)	1.76 (48.33)	0.24 (6.67)
Agrihorticulture System (AH)			
E1N	3.63 (73.33)	0.58 (11.67)	0.74 (15.00)
E1S	2.83 (71.67)	0.72 (18.33)	0.40 (10.00)
E2N	2.73 (68.33)	0.93 (23.33)	0.33 (8.33)
E2S	2.00 (66.67)	0.80 (26.50)	0.21 (7.00)
E3N	0.91 (49.17)	0.86 (46.50)	0.08 (4.50)
E3S	0.54 (40.00)	0.75 (55.83)	0.06 (4.17)

*Numeric value in parenthesis shows % value.

In the agrisilivihorticulture (ASH) system trees availability ranged from (45.00%) in site E3S to (56.67%) in site E1N. Availability of saplings were found between (48.33%) to (34.29%) in the site E3S and E1S while the seedlings availability was higher 6.67%) in the site E3S. In agrihorticulture (AH) system trees varied from (40.00%) in site E3S to (73.33%) in site E1N while the presence of sapling ranged from (11.67%) to (23.33%) in the site E1N and E2N. Availability of seedlings varied from (4.17%) in site E3S to (6.67%) in site E1N (Table 4 and Figure 4).

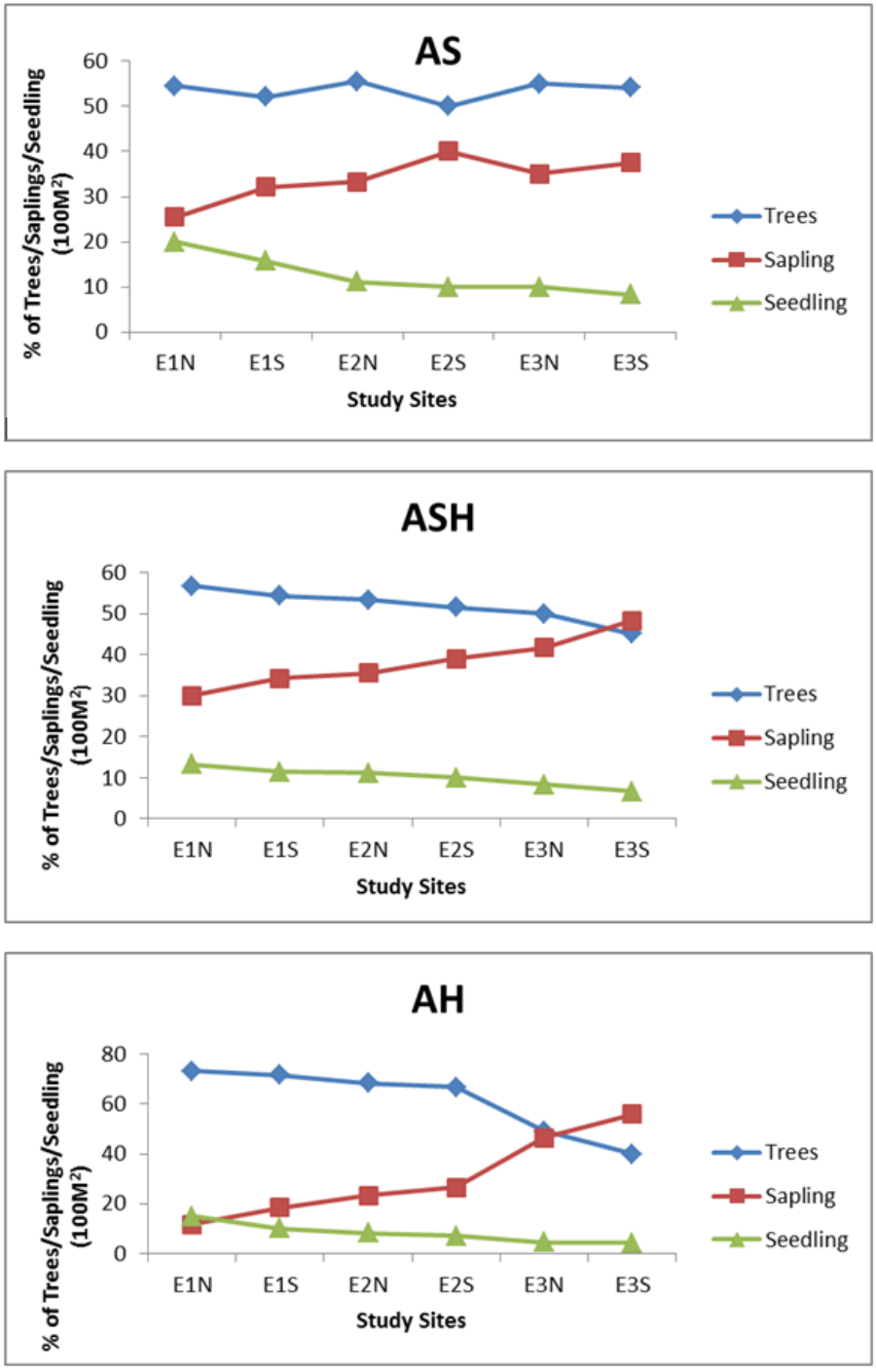

Figure 4. Distribution percentage of Trees, Saplings and Seedlings in Traditional Agroforestry

Tree seedlings were generally present on all the agricultural fields less in numbers as farmers believed that the seedlings posed difficulties for ensuring efficient cultural operations; therefore they generally uproot these from the fields. Natural regeneration was found higher in the forest tree species under agrisiliviculture system and agrisilvihorticulture system due to plentiful seed dispersal by natural means whereas this phenomenon was not common for fruit tree species (horticultural trees). It is also clear from data given in Table 4 that the more number of seedlings present on northern aspect as compared to southern aspect because in southern aspect solar radiations directly falls on the earth, this reduces the soil moisture, warms the earth etc while in the northern aspect these are present in sufficient quantity to enhance the natural regeneration and tree growth. That is the reason that vegetation (tree density) on the northern slope is found generally denser comparatively to southern aspect. The number of seedling present on agricultural field decreased with an increase in elevation this might be due to the

difficulty in germination of seed in cold and unfavourable conditions in the higher elevation, therefore in general the poor regeneration was reported. Cathy Watson [6] stressed the need for farmer-managed natural regeneration: an agroforestry practice -- easy, fast and richly rewarding as it get the right tree for the right place for the right reason.

3.4. Distribution of Trees (structure) in Different Diameter and Height Classes in Traditional Agroforestry Systems

In present study the trees were present up to as high as 60-70cm and 70-80cm diameter class and 15-20m height class. In AS system (elevation 1000-1500m), the maximum numbers of trees (each 2.65/100m^2) were recorded under 20-30cm diameter class both on northern and southern aspect (site- E1N-AS and E1S-AS). In the elevation 1500-2000m, the maximum numbers of trees (2.30/100m^2) were recorded on northern aspect in site E2N-AS under 10-20cm diameter class followed by southern aspect in site-E2S-AS (2.00/100m^2) under 20-30 cm diameter class (Table 4). In higher elevation (2000-2500m) on northern aspect the maximum numbers of tree (2.10/100m^2) were recorded under 30-40cm diameter class (site-E3N-AS) while lowest numbers of trees in this site were recorded under diameter 70-80cm diameter class. On the southern aspect (site- E3S-AS) of 2000-25000m the maximum numbers of tree were recorded (1.60/100m^2) under 30-40 cm diameter class and least numbers of trees (0.10/100m^2) under 60-70cm diameter class (Table 5 and Figure 5). In height class of agrisilviculture system, highest numbers of trees (3.95 /100m^2) were recorded under 5-10m height class in the southern aspect of elevation 1000-1500m followed by the northern aspect of same elevation in same height class. In the elevation 1500-2000m, the highest numbers of trees (3.00/100m^2 and 2.15/100m^2) were recorded under 10-15m highest class, both in northern and southern aspect respectively while the least numbers of trees (0.70/100m^2 and 0.80/100m^2) were recorded in the 15-20m height class on both aspect of this elevation. In the higher elevation (2000-2500m), the maximum numbers of trees (2.65/100m^2) were observed in the northern aspect under 15-20m height class. In the southern aspect of same elevation (2000-2500m) again recoded maximum tree numbers (2.45/100m^2) in height class 10-15m followed by the height class 15-20m (Table 5 and Figure 5).

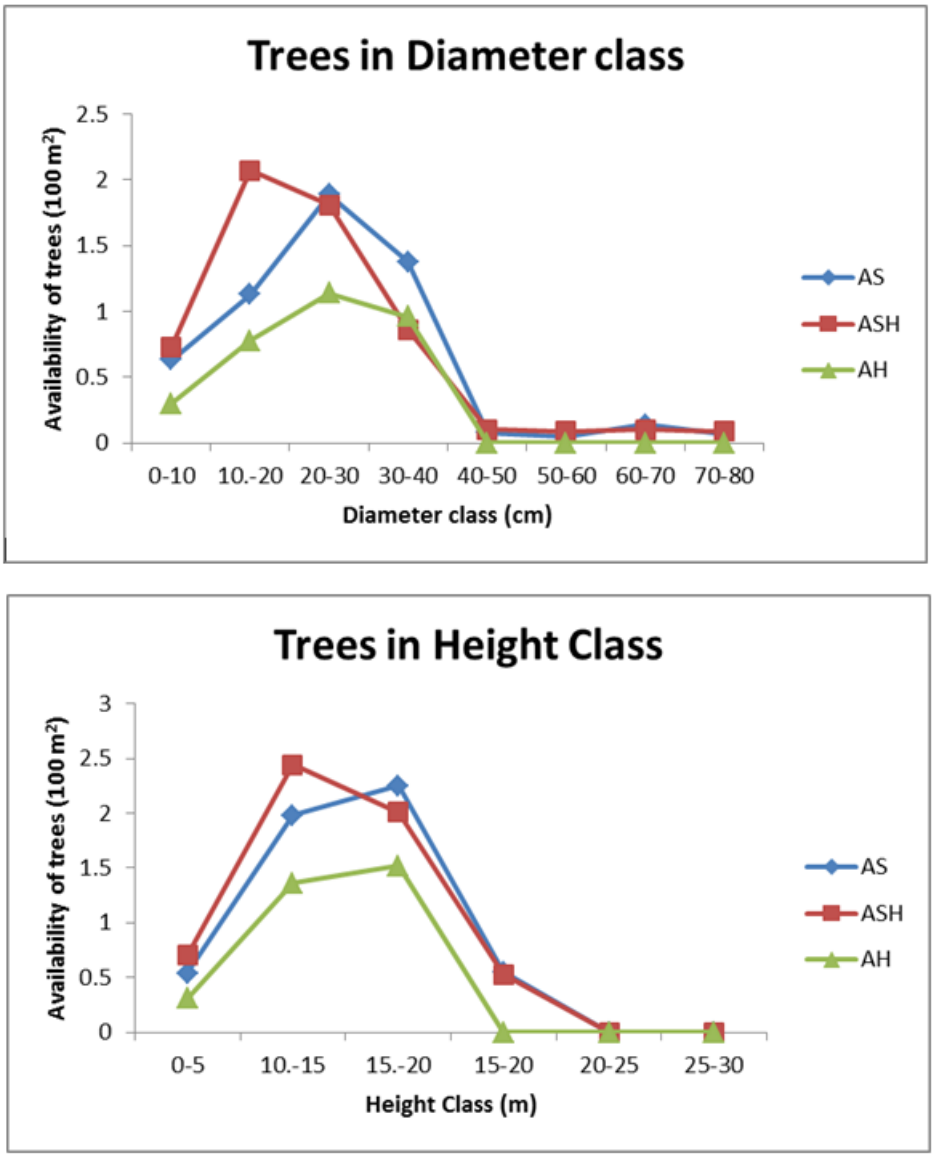

Figure 5. Distribution of Trees in diameter and height classes

Table 5. Distribution of trees (per 100 m^2) in various diameter and height class under the Agrisilviculture system (AS) in Uttarkashi District

AFS/Site	Trees under Diameter class (cm)								Trees under Height Class (m)					
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	0-5	5-10	10-15	15-20	20-25	25-30
AS/E1N	2.40	0.85	2.65	1.15	0.20	0.10	-	-	2.40	3.60	1.35	-	-	-
AS/E1S	0.85	2.30	2.65	0.60	0.15	-	0.10	-	0.85	3.95	1.90	-	-	-
AS/E2N	-	2.3	1.65	1.45	0.10	-	0.20	-	-	2.00	3.00	0.70	-	-
AS/E2S	0.50	0.35	2.00	1.36	-	0.20	0.14	-	-	1.60	2.15	0.80	-	-
AS/E3N	-	0.60	1.25	2.10	-	-	0.30	0.10	-	0.35	2.65	1.10	-	-
AS/E3S	-	0.40	1.15	1.60	-	-	0.10	0.30	-	0.40	2.45	0.70	-	-
Mean	0.63	1.13	1.89	1.38	0.08	0.05	0.14	0.07	0.54	1.98	2.25	0.55	-	-

In agrisilvihoticulture system (ASH) in the elevation 1000-1500m, the trees in different diameter class varied from 0.10/100m^2 to 3.60/100m^2. On the northern aspect (site- E1N-ASH) the maximum number of trees (3.60/100m^2) found under 10-20cm diameter class while the least number of trees (0.10) were recorded under 50-60 cm diameter class. On the southern aspect of this elevation (site- E1S-AS) again recorded maximum numbers of tree (2.70/100m^2) in diameter class 10-20cm followed by the diameter class 20-30cm where numbers of tree were recorded as 1.60/100m^2. In the elevation 1500-2000m on northern aspect (site- E2N-ASH) maximum numbers of trees (3.00/100m^2) were recorded in diameter class 10-20cm while on the southern aspect (site- E2S-ASH) maximum numbers of trees (2.10/100m^2) were found under diameter class 20-30cm. In the agrisilvihorticulture system of the elevation 2000-2500m, the maximum numbers of trees (2.05/100m^2) were recorded in northern aspect under 20-30 diameter class while the lowest numbers of trees (0.05/100m^2) were recorded in diameter class 50-60cm in southern aspect (site- E3S-ASH). Distribution of numbers of tree per 100m^2 under various diameter class in agrisilvihorticulture system is presented in Table 6. Results on agrisilvihorticulture system for height class revealed, maximum numbers of trees for 5-10m and 10-15m height class. The maximum value (4.70/100m^2) of tree numbers were recorded in height class 5-10m in the southern aspect of 1000-1500m of elevation while the least numbers of tree (0.40/100m^2) were observed on the southern aspect of 1500-2000m elevation under 15-20m height class. In agrisilvihorticulture system of higher elevation (2000-2500m), the highest numbers of tree (2.60/100m^2 and 2.30/100m^2) were recorded on both northern and southern aspect under height class 10-15m while lowest numbers of trees (0.55/100m^2) were recorded under 5-10m height class on the northern aspect of this elevation (Table 6).

Table 6. Distribution of trees (per 100 m^2) in diameter and height class under the Agrisilvihorticulture system (ASH) in Uttarkashi District

AFS/Site	Trees under Diameter class (cm)								Trees under Height Class (m)					
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	0-5	5-10	10-15	15-20	20-25	25-30
ASH/E1N	1.50	3.60	2.05	-	0.20	0.10	-	-	1.50	3.65	2.29	-	-	-
ASH/E1S	1.10	2.70	1.60	1.10	0.25	0.30	-	-	1.30	4.70	1.05	-	-	-
ASH/E2N	0.75	3.00	1.95	0.45	-	0.10	0.20	-	0.65	3.95	1.85	-	-	-
ASH/E2S	1.05	1.65	2.10	0.65	0.15	-	0.30	-	0.75	1.80	1.95	0.40	-	-
ASH/E3N	-	0.45	2.05	1.75	-	-	0.10	0.20	-	0.55	2.60	1.40	-	-
ASH/E3S	-	1.00	1.10	1.20	-	0.05	-	0.35	-	-	2.30	1.35	-	-
Mean	0.73	2.07	1.81	0.86	0.10	0.09	0.10	0.09	0.70	2.44	2.01	0.53	-	-

In the agrihorticulture (AH) system the maximum numbers of trees (1.90/100m^2) were recorded in diameter class 30-40 cm in site E1N-AH and lowest numbers of trees (0.30) were recorded in site E3S-AH under same diameter class. In the elevation 1000-1500m, the maximum numbers of trees (1.90/100m^2) were recorded in diameter class 30-40cm in northern aspect (site- E1N-AH) while in the southern aspect (site- E1S-AH) it was recorded maximum (1.45/100m^2) under 10-20cm diameter class. In the elevation 1500-2000m, the maximum numbers of trees (1.75/100m^2) were recorded in the diameter class 20-30cm in northern aspect (site- E2N-AH) while in southern aspect (site- E2S-AH), the maximum tree numbers (1.20/100m^2) were recorded in diameter class 10-20cm diameter class. In the higher elevation (2000-2500m), maximum numbers of trees (0.95/100m^2) were recorded on northern aspect (site-E3N-AH) under 30-40cm diameter class while on southern aspect (site-E3S-AH) maximum trees (1.05/100m^2) were recorded under 20-30cm diameter classes (Table 7). In the agrihorticulture system maximum numbers of trees (3.15/100m2) were recorded under height class 5-10m on the northern aspect of 1000-15000m elevation while the least numbers of trees (0.55/100m2) were recorded on the both northern and southern aspect of 1500-2000m elevation under 0-5m height class. However, average numbers of tree (1.52/100m2) were higher in the 10-15m height class (Table 7).

Table 7. Distribution of trees (per 100 m^2) in various diameter and height class under the Agrihorticulture system (AH) in Uttarkashi District

AFS/Site	Trees under Diameter class (cm)								Trees under Height Class (m)					
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	0-5	5-10	10-15	15-20	20-25	25-30
AH/E1N	0.75	0.95	1.35	1.90	-	-	-	-	0.75	3.15	1.05	-	-	-
AH/E1S	-	1.45	1.15	1.35	-	-	-	-	-	1.45	2.50	-	-	-
AH/E2N	0.45	1.10	1.75	0.70	-	-	-	-	0.55	1.50	1.95	-	-	-
AH/E2S	0.60	1.20	0.65	0.55	-	-	-	-	0.55	1.15	1.30	-	-	-
AH/E3N	-	-	0.90	0.95	-	-	-	-	-	0.90	0.95	-	-	-
AH/E3S	-	-	1.05	0.30	-	-	-	-	-	-	1.35	-	-	-
Mean	0.30	0.78	1.14	0.96	-	-	-	-	0.31	1.36	1.52	-	-	-

In the fruit trees the volume of wood and canopy size did not make much difference as in timber trees. The higher productivity of temperate fruits, especially in apple trees was recorded under 0-10 and 10-20cm diameter class (lower diameter) because the trees of higher diameter classes are usually harvested as the main objective of these trees to produce fruits thus, most of the trees recorded in lower diameter classes. In present study, the availability of number of trees decreases with the increase of diameter/girth class, similar results were obtained from the study conducted by Gupta Joshi [11], Sahu et al. [27], Powers et al. [24], McLaren et al. [18], Parthasarathy and Karthikeyan [22] Similar pattern of a continuous decrease of number of tree individuals from lower to upper diameter classes was also noticed by Biswas and Misbahuzzaman [5]. Banerjee and Dhara [2] evaluated different agri-horti-silvicultural Models and found all them while mainting agrodivesity also multifarious utility to framers. Devaranavadgi et al [8] reported in Northen Karnataka five hill districts that bund planting was found to be most prominent agroforestry practice both in rainfed and irrigated (88% and 86%) situations followed by scattered planting. Among the choice of species followed the trend fruits, timber and fuel wood. Denis [7], Manoj et al [16] and VinodKumar [39] also advocated the role of diverse agroforestry prctices for economic and ecological sustenance of the agro-ecosystem and conservation of biodiversity.

The study inferred that under traditional agroforestry practices in Uttarkashi region of Uttrakhand the most widely adaptable system in terms of tree diversity, structure and composition is agrisilvihorticutural (ASH) system. It combines different component and gives diverse produce utilizing the better field space in hills with specialize techniques of land utilization. In terms of economic gain obviously Agrihorticulture (AH) system is more preferred however, this system is less diverse as structure and composition of trees diversity is low. The Agrisilvi (AS) system is practiced in high altitude for fuel, fodder and conservation purpose due to limitation of land use for other purpose however it is ecologically sound and sustainable system. The implication of the present study suggests local farmers for practicing of AS in higher hills which are ecologically frazil and ASH and AH in the areas which are flat and ecologically less sensitive, moreover for economic point of view farmers need to practice agricultural crops in fruit orchard in the form of AH systems.

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