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Economic Productivity of the Agroforestry Systems in Shimla District of Himachal Pradesh, India

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ABSTRACT: The study was conducted in the Shimla district of Himachal Pradesh during the year 2021-2023 in context of economic productivity of the prevalent agroforestry systems along the different altitudinal zones. The district was divided into three altitudinal zones *viz.*, altitudinal zone-I (1500-2000 m amsl), altitudinal zone-II (2000-2500 m amsl), and altitudinal zone-III (above 2500 m amsl) and three-Gram Panchayats were selected from each altitudinal zone, further 15 farmers were selected within each Panchayat, including five marginal, small, and semi-medium farmers. Agroforestry practices were categorized into six land use systems *viz.*, agrihorticulture, hortiagriculture, agrihortisilviculture, hortiagrisilviculture, hortipastoral and pastoralsilviculture systems. Results revealed that economic productivity was significantly affected by the farmers categories land use systems along the altitudinal zones. The cost of cultivation, net returns and benefit: cost ratio of the prevalent agroforestry systems among the different farmers categories along the altitudinal zones of Shimla district of Himachal Pradesh was found the highest under the semi-medium farmers category and lowest under the marginal farmers category. The cost of cultivation was found significantly affected by the different agroforestry systems being practiced with maximum cost of cultivation (Rs 8,05,658 $ha^{-1}yr^{-1}$) recorded under hortiagriculture system in altitudinal zone-III. The higher gross returns (Rs 24,02,464 $ha^{-1}yr^{-1}$) and net returns (Rs 15,96,806 $ha^{-1}yr^{-1}$) recorded under hortiagriculture system in altitudinal zone-III. The Benefit: Cost Ratio were found significantly affected by the different agroforestry systems being practiced with maximum (3.21) recorded under pastoralsilviculture system in altitudinal zone-I. This study offers a useful approach for selecting different agroforestry systems to maximize profits and further help to improve the socio-economic status of farmers in North Western Himalayas.

Keywords: Agroforestry, Economic, marginal farmer and productivity.

INTRODUCTION

Agroforestry is a climate-resilient land use technique that increases biodiversity and intensifies various ecosystem services (Raj *et al*., 2024). According to Kumar *et al*. (2024), the agroforestry system is the most effective way for India to meet its net zero carbon emissions target. The agroforestry has become recognized as a holistic use of agricultural land that preserves natural assets (Dmuchowski *et al*., 2024). The promotion of agroforestry systems necessitates a multifaceted approach that considers the social, economic, and environmental aspects of sustainable development. The agroforestry system has been recognized as a critical ecosystem service provider because to its ability to improve biodiversity, soil conservation, carbon sequestration, and water control (Giri *et al*., 2024). Adoption of agroforestry technologies is critical to addressing the ongoing degradation of forest resources and improving farmers' livelihoods (Alemayehu & Simeneh 2024; Pattanaik and Priyadarshini 2023). Agroforestry would alleviate poverty, promote food security, generate income, and empower tribal and rural communities (Bhattacharya, 2024).

Agroforestry is one of the finest options for crop diversification and economic upliftment in the Indian Himalayan regions (Garima *et al*., 2021). Agroforestry is a climate-smart multifunctional system that has traditionally contributed to enhancing climate resilience (Sharma and Pant 2017) and is considered a primer for concealing the ill effects of climate variability (Sharma *et al*., 2022). Such multifunctional systems are more complex due to augmented intra and interspecific competition amongst the diverse components that regulate its functional processes (Verma *et al*., 2023). Therefore, in-depth knowledge of various interacting processes in agroforestry systems is essential

(Saneinejad *et al*., 2014). Agroforestry has the potential to improve the socio-ecological and socio-economic conditions of Indigenous peoples while also improving mountain ecosystem services. Traditional agroforestry practices reported in the North-Western Himalayan region include Agrisilviculture, Agrihorticulture, Agrisilvihorticulture, Agrihortisilviculture, Hortisilviculture, Silvipastoral, Pastoralsilviculture, Agrisilvipastoral and Pastoralsilvihorticulture (Sharma *et al.*, 2022). The land use systems in the state are undergoing upheaval as a result of fast changes in farmers socio-economic position, industrialization, climate change, and government regulations. There has been little research into the influence of climate change on agroforestry resources, socio-economic conditions, mitigation, and adaptation. Therefore, accurate estimation of economic productivity in the different agroforestry systems is the focus of current research. The present investigation was carried out to examine how the prevalent agroforestry systems impact economic productivity in Shimla district of Himachal Pradesh.

MATERIAL AND METHODS

The present study was conducted during 2021-2023 in Shimla district of Himachal Pradesh along the altitudinal range between 1500 m amsl to above 2500 m amsl. Shimla district is located in the western part of Himachal Pradesh between latitudes 32°45' and 31°44' and longitudes 77°00' and 78°19'. The climate in Shimla district is predominantly cool during winter, moderately warm during summer which fall under high hill wet temperate agro-climate zone of Himachal Pradesh. Temperature typically ranges from 4.0°C to 31.0°C over the course of year. The average temperature during summer is 19.0°C and 28.0°C, and in winter 1.0°C and 10.0°C. Monthly precipitation varies from 15.0 mm in November to 434.0 mm in August. It is typically around 45.0 mm per month during winter and spring, 175.0 mm in June. The average total precipitation is 1575.0 mm which is less than other hill stations. Snowfall in this region occurs in the months of December to February.

A. Cost of cultivation

Cost of cultivation is the total amount of expenditure (variable and fixed cost) done on producing yield.

B. Gross return

The utilizable biomass of each functional unit in a system was given the current market value for estimating total return from a system.

C. Net returns

Net Return = Gross return – Production cost

(i) Benefit: Cost ratio

Benefit: cost ratio of the system was calculated by dividing total discounted benefits with total discounted costs of the system.

$$\text{Benefit : Cost Ratio} = \frac{\text{Total discounted benefits}}{\text{Total discounted costs}}$$

RESULTS AND DISCUSSION

A. Cost of cultivation (Rs $ha^{-1}yr^{-1}$)

(i) Altitudinal Zone-I. Data on effect of farmers categories on the cost of cultivation incurred for various prevalent agroforestry systems in altitudinal zone-I of Shimla district of Himachal Pradesh has been presented in Table 1. Considering the different farmers categories, cost of cultivation for different farmers categories were observed highest semi-medium farmers category (Rs 3,50,036 ha^{-1} yr^{-1}) followed by small farmers category (Rs 3,35,214 ha^{-1} yr^{-1}) and marginal farmers category (2,92,787 ha^{-1} yr^{-1}). Within agroforestry systems, the highest cost of cultivation (Rs 5,42,163 ha^{-1} yr^{-1}) were incurred for the hortiagriculture system, while the minimum (Rs 23,654 ha^{-1} yr^{-1}) cost of cultivation were observed for pastoralsilviculture system. In terms of interaction, the cost of cultivation was highest (Rs 6,02,010 ha^{-1} yr^{-1}) for the hortiagriculture system under the small farmers category, while the minimum (Rs 20,180 ha^{-1} yr^{-1}) was observed for the pastoralsilviculture system under the marginal farmers category.

(ii) Altitudinal Zone-II. The information presented in Table 1 indicates that the cost of cultivation incurred for various prevalent agroforestry systems in altitudinal zone-II. Among the different farmers categories, the maximum cost of cultivation (Rs 4,64,397 ha^{-1} yr^{-1}) were observed under the semi-medium farmers category, while the minimum (Rs 4,07,827 ha^{-1} yr^{-1}) were found for the marginal farmers category. For all agroforestry systems, the highest cost of cultivation (Rs 6,36,897 ha^{-1} yr^{-1}) were incurred for the hortiagriculture system, which was statistically at par with the cost of cultivation for hortipastoral system (Rs 6,35,725 ha^{-1} yr^{-1}) and the minimum cost of cultivation (Rs 34,808 ha^{-1} yr^{-1}) were observed for pastoralsilviculture system. Regarding interaction, the cost of cultivation was highest (Rs 6,98,220 ha^{-1} yr^{-1}) for the hortiagriculture system practiced by small farmers category, while the minimum (Rs 31,170 ha^{-1} yr^{-1}) were found for the pastoralsilviculture system under the marginal farmers category.

(iii) Altitudinal Zone-III. The data presented in Table 1 revealed that the cost of cultivation incurred for various prevalent agroforestry systems in altitudinal zone-III. For different farmers categories, the highest cost of cultivation (Rs 6,22,575 ha^{-1} yr^{-1}) were observed under the semi-medium farmers category and the lowest (Rs 5,65,387 ha^{-1} yr^{-1}) were found for the marginal farmers category. Among various agroforestry systems, the highest cost of cultivation (Rs 8,05,658 ha^{-1} yr^{-1}) were incurred for the hortiagriculture system which was statistically at par with the cost of cultivation for hortipastoral system (Rs 8,00,680 ha^{-1} yr^{-1}) while the minimum cost of cultivation was found for pastoralsilviculture system (Rs 38,547 ha^{-1} yr^{-1}). In terms of interaction, the cost of cultivation was highest (Rs 8,65,775 ha^{-1} yr^{-1}) for the hortiagriculture system under the small farmers category, while the minimum (Rs 35,060 ha^{-1} yr^{-1}) were found for the pastoralsilviculture system under the marginal category.

Table 1: Cost of cultivation (Rs ha^{-1}yr^{-1}) of prevalent agroforestry systems among different farmers categories in Shimla district (H.P.)

Total Expenses (Rs ha^{-1}yr^{-1})				
Altitudinal Zone-I				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	191320	221415	311255	241330
HA	502450	602010	522030	542163
AHS	242780	277760	332640	284393
HAS	292660	305690	382870	327073
HP	507330	582310	522740	537460
PS	20180	22101	28680	23654
Mean	292787	335214	350036	
Altitudinal Zone-II				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	287220	315215	404624	335686
HA	597340	698220	615130	636897
AHS	437970	452760	527690	472807
HAS	487840	502975	577670	522828
HP	605420	680330	621425	635725
PS	31170	33415	39840	34808
Mean	407827	447153	464397	
Altitudinal Zone-III				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	456480	486350	576090	506307
HA	765590	865775	785610	805658
AHS	657360	672250	747055	692222
HAS	707180	722530	797360	742357
HP	770650	845625	785765	800680
PS	35060	37010	43570	38547
Mean	565387	604923	622575	

*Where, AH-Agrihorticulture, HA-Hortiagriculture, AHS-Agrihortisilviculture, HAS-Hortiagrisilviculture, HP- Hortipastoral, PS- Pastoralsilviculture

B. Gross Returns (Rs ha^{-1}yr^{-1})

(i) Altitudinal Zone-I. Upon reviewing the data presented in Table 2 showed that the gross returns obtained from the various prevalent agroforestry systems in altitudinal zone-I in Shimla district of Himachal Pradesh. Midst of the different farmers categories, the maximum gross returns (Rs 8,41,500 ha^{-1} yr^{-1}) were found under the semi-medium farmers category, while the minimum (Rs 6,87,971 ha^{-1} yr^{-1}) were observed for the small farmers category. Among various agroforestry systems, the maximum gross returns (Rs 14,09,347 ha^{-1} yr^{-1}) were obtained for the hortiagriculture system, while the minimum gross returns (Rs 75,995 ha^{-1} yr^{-1}) were found for pastoralsilviculture system. In terms of interaction, gross returns were highest (Rs 15,47,166 ha^{-1} yr^{-1}) for the hortiagriculture system under the small farmers category, while the minimum (Rs 65,005 ha^{-1} yr^{-1}) were found for the pastoralsilviculture system under the marginal farmers category.

(ii) ltitudinal Zone-II. The information presented in Table 2 suggests that the gross returns obtained from various prevalent agroforestry systems in altitudinal zone-II. Considering different farmers categories, the maximum gross returns (Rs 12,38,066 ha^{-1} yr^{-1}) were found under the semi-medium farmers category and the minimum (Rs 10,56,072 ha^{-1} yr^{-1}) were observed for the marginal farmers category. Among all the agroforestry systems, the maximum gross returns (Rs 18,35,231 ha^{-1} yr^{-1}) were obtained for the hortiagriculture system and the minimum gross returns (Rs 1,10,258 ha^{-1} yr^{-1}) were found for pastoralsilviculture system. In terms of interaction, gross returns were highest (Rs 20,24,838 ha^{-1} yr^{-1}) for the hortiagriculture system practiced by small category farmers, while the minimum (Rs 96,627 ha^{-1} yr^{-1}) were found for the pastoralsilviculture system under the marginal category farmers.

(iii) Altitudinal Zone-III. The data presented in Table 2 indicates that the gross returns obtained from various prevalent agroforestry systems in altitudinal zone-III. For different farmers categories, the gross returns were found highest in semi-medium (Rs 17,16,875 ha^{-1} yr^{-1}) followed by small (Rs 16,25,333 ha^{-1} yr^{-1}) and marginal (Rs 14,53,291 ha^{-1} yr^{-1}) farmers categories. For different agroforestry systems, the maximum gross returns (Rs 24,02,464 ha^{-1} yr^{-1}) were recorded for the hortiagriculture system, while the minimum gross returns were found for pastoralsilviculture (Rs 120224 ha^{-1} yr^{-1}). In terms of interaction, gross returns were highest (Rs 26,05,983 ha^{-1} yr^{-1}) for the hortiagriculture system under the small farmers category and the minimum (Rs 1,06,582 ha^{-1} yr^{-1}) were found for the pastoralsilviculture system under the marginal farmers category.

Table 2: Gross Returns (Rs $ha^{-1}yr^{-1}$) of prevalent agroforestry systems among different farmers categories in Shimla district (H.P.)

Gross Returns (Rs $ha^{-1}yr^{-1}$)				
Altitudinal Zone-I				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	279467	354264	513571	382434
HA	1266174	1547166	1414701	1409347
AHS	541399	622182	755093	639558
HAS	702384	736713	934203	791100
HP	1273398	1467421	1338403	1359741
PS	65005	69951	93029	75995
Mean	687971	799616	841500	
Altitudinal Zone-II				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	505507	567387	740462	604452
HA	1678525	2024838	1802331	1835231
AHS	1091807	1154538	1387825	1211390
HAS	1299059	1368092	1617476	1428209
HP	1664905	1911727	1752419	1776350
PS	96627	106260	127886	110258
Mean	1056072	1188807	1238066	
Altitudinal Zone-III				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	812534	905219	1094571	937441
HA	2189587	2605983	2411823	2402464
AHS	1644950	1725970	2039602	1803507
HAS	1889838	1977892	2312495	2060075
HP	2076254	2421836	2303769	2267286
PS	106582	115101	138988	120224
Mean	1453291	1625333	1716875	

Where, AH-Agrihorticulture, HA-Hortiagriculture, AHS-Agrihortisilviculture, HAS-Hortiagrisilviculture, HP- Hortipastoral, PS-Pastoralsilviculture

C. Net Returns (Rs $ha^{-1}yr^{-1}$)

(i) Altitudinal Zone-I. The analysis of the data presented in Table 3 revealed that the net returns obtained from various prevalent agroforestry systems in altitudinal zone-I in Shimla district of Himachal Pradesh. Considering different farmers categories, the semi-medium farmers category resulted in maximum net returns (Rs 4,91,464 ha^{-1} yr^{-1}), while the minimum (Rs 3,95,185 ha^{-1} yr^{-1}) was observed for the marginal farmers category. Among the different agroforestry systems, the maximum net returns (Rs 8,67,184 ha^{-1} yr^{-1}) were obtained from hortiagriculture system and minimum net return (Rs 52,341 ha^{-1} yr^{-1}) were obtained from pastoralsilviculture system. In terms of interaction, net returns were highest (Rs 9,45,156 ha^{-1} yr^{-1}) for the hortiagriculture system practiced by small farmerss, while the minimum (Rs 44,825 ha^{-1} yr^{-1}) were found for the pastoralsilviculture system in the marginal farmers category.

(ii) Altitudinal Zone-II. The information presented in Table 3 indicates the net returns obtained from various prevalent agroforestry systems in altitudinal zone-II. For different farmers categories, net returns were found in the order of semi-medium (Rs 7,73,670 ha^{-1} yr^{-1}), small (Rs 7,41,655 ha^{-1} yr^{-1}), and marginal (Rs 6,48,245 ha^{-1} yr^{-1}) farmers category. Taking into consideration all the agroforestry systems, the maximum net returns (Rs 11,98,335 ha^{-1} yr^{-1}) were obtained from the hortiagriculture system which was statistically at par with hortipastoral system (Rs 11,40,625 ha^{-1} yr^{-1}) and the minimum net returns (Rs 75,449 ha^{-1} yr^{-1}) were found from pastoralsilviculture system. In terms of interaction, net returns were found maximum (Rs 13,26,618 ha^{-1} yr^{-1}) for the hortiagriculture system practiced by small category farmers and the minimum (Rs 65,457 ha^{-1} yr^{-1}) was observed for the pastoralsilviculture system under the marginal farmers category.

(iii) Altitudinal Zone-III. The data presented in Table 3 showed that the net returns obtained from various prevalent agroforestry systems in altitudinal zone-III. Among the different farmers categories, net returns were found highest in semi-medium (Rs 10,94,300 ha^{-1} yr^{-1}) farmers category which was statistically at par with small (Rs 10,20,410 ha^{-1} yr^{-1}) farmers category and minimum was in marginal farmers category (Rs 8,87,904 ha^{-1} yr^{-1}). Among the different agroforestry systems, the maximum net returns (Rs 15,96,806 ha^{-1} yr^{-1}) were recorded for the hortiagriculture system, while the minimum net returns (Rs 81,677 ha^{-1} yr^{-1}) were found for pastoralsilviculture system. For the interaction, net returns were found maximum (Rs 17,40,208 ha^{-1} yr^{-1}) for the hortiagriculture system under the small farmers category and the minimum (Rs 71,522 ha^{-1} yr^{-1}) was observed for the pastoralsilviculture system under the marginal farmers category.

Table 3: Net Returns (Rs ha^{-1}yr^{-1}) of prevalent agroforestry systems among different farmers categories in Shimla district (H.P.).

Net Returns (Rs ha^{-1}yr^{-1})				
Altitudinal Zone-I				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	88147	132849	202316	141104
HA	763724	945156	892671	867184
AHS	298619	344422	422453	355165
HAS	409724	431023	551333	464027
HP	766068	885111	815663	822281
PS	44825	47850	64349	52341
Mean	395185	464402	491464	
Altitudinal Zone-II				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	218287	252172	335838	268766
HA	1081185	1326618	1187201	1198335
AHS	653837	701778	860135	738583
HAS	811219	865117	1039806	905381
HP	1059485	1231397	1130994	1140625
PS	65457	72845	88046	75449
Mean	648245	741655	773670	
Altitudinal Zone-III				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	356054	418869	518481	431135
HA	1423997	1740208	1626213	1596806
AHS	987590	1053720	1292547	1111286
HAS	1182658	1255362	1515135	1317718
HP	1305604	1576211	1518004	1466606
PS	71522	78091	95418	81677
Mean	887904	1020410	1094300	

Where, AH-Agrihorticulture, HA-Hortiagriculture, AHS-Agrihortisilviculture, HAS-Hortiagrisilviculture, HP- Hortipastoral, PS-Pastoralsilviculture

D. Benefit: Cost Ratio

(i) Altitudinal Zone-I. Upon reviewing the data presented in Table 4 revealed that the benefit-to-cost ratio for various prevalent agroforestry systems in altitudinal zone-I in Shimla district of Himachal Pradesh. Considering different farmers categories, the highest benefit: cost ratio was recorded for the semi-medium farmers category (2.48) which was statistically at par for the small farmers category (2.42) and lowest was recorded for the marginal farmers category (2.39). Among the different agroforestry systems, the maximum benefit: cost ratio (3.21) was incurred for the pastoralsilviculture system, while the minimum benefit: cost ratio was found for agrihorticulture system (1.57). For interaction effects, the benefit: cost ratio was found maximum (3.24) for the pastoralsilviculture system practiced by semi-medium farmers category and the minimum benefit: cost ratio (1.46) was observed for the agrihorticulture system by marginal farmers category.

(ii) Altitudinal Zone-II. The information presented in Table 4 showed that the benefit: cost ratio for various prevalent agroforestry systems in altitudinal zone-II. The benefit: cost ratio varied among different farmers categories, with the maximum ratio of 2.70 observed under the semi-medium farmers category, and the minimum ratio of 2.60 found for the marginal farmers category. Among all the agroforestry systems, the maximum ratio of 3.16 was observed for pastoralsilviculture system, indicating that this system generated relatively higher benefits compared to its costs. On the other hand, the minimum benefit: cost ratio of 1.80 was found for hortiagriculture system. For interaction, the maximum benefit: cost ratio (3.21) was found in the pastoralsilviculture system practiced by semi-medium farmers category, while the minimum ratio (1.76) was observed in the agrihorticulture system under the marginal farmers category.

(iii) Altitudinal Zone-III. Table 4 data revealed that the benefit: cost ratio for various prevalent agroforestry systems in altitudinal zone-III. Among the different farmers categories, the highest benefit: cost ratio was recorded for the semi-medium farmers category (2.79) followed by the small farmers category (2.69) and the marginal farmers category (2.59). Within the different agroforestry systems, the maximum benefit: cost ratio (3.11) was obtained for the pastoralsilviculture system and the minimum benefit: cost ratio was found for agrihorticulture system (1.85). For interaction, the benefit: cost ratio was found maximum (3.19) for the pastoralsilviculture system under the semi-medium farmers category and the minimum (1.78) was observed for the agrihorticulture system under the marginal farmers category.

Table 4: Benefit: Cost ratio (BCR) of prevalent agroforestry systems among different farmers categories in Shimla district (H.P.)

Benefit: Cost ratio (BCR)				
Altitudinal Zone-I				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	1.46	1.60	1.65	1.57
HA	2.52	2.57	2.71	2.60
AHS	2.23	2.24	2.27	2.25
HAS	2.40	2.41	2.44	2.42
HP	2.51	2.52	2.56	2.53
PS	3.22	3.17	3.24	3.21
Mean	2.39	2.42	2.48	
Altitudinal Zone-II				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	1.76	1.80	1.83	1.80
HA	2.81	2.90	2.93	2.88
AHS	2.49	2.55	2.63	2.56
HAS	2.66	2.72	2.80	2.73
HP	2.75	2.81	2.82	2.79
PS	3.10	3.18	3.21	3.16
Mean	2.60	2.66	2.70	
Altitudinal Zone-III				
Agroforestry Systems (AFS)	**Farmers Category (FC)**			**Mean**
	Marginal	**Small**	**Semi-medium**	
AH	1.78	1.86	1.90	1.85
HA	2.86	3.01	3.07	2.98
AHS	2.50	2.57	2.73	2.60
HAS	2.67	2.74	2.90	2.77
HP	2.69	2.86	2.93	2.83
PS	3.04	3.11	3.19	3.11
Mean	2.59	2.69	2.79	

Where, AH-Agrihorticulture, HA-Hortiagriculture, AHS-Agrihortisilviculture, HAS-Hortiagrisilviculture, HP- Hortipastoral, PS-Pastoralsilviculture

The cost of cultivation of the prevalent agroforestry systems among the different farmers categories along the altitudinal zones of Shimla district of Himachal Pradesh was found the highest under the semi-medium farmers category (Rs 6,22,575 $ha^{-1}yr^{-1}$) in altitudinal zone-III and lowest under the marginal farmers category (Rs 2,92,787 $ha^{-1}yr^{-1}$) in altitudinal zone-I (Table 4). The maximum cost of cultivation under semi-medium farmers category may be due to farmers might have invest more in machinery, labour, and inputs to manage their larger farms efficiently. The semi-medium farmers may employ more intensive farming practices, such as higher usage of fertilizers, pesticides, and modern agricultural technologies, to maximize their yields. These inputs come with a cost, contributing to the higher cost of cultivation. Similar results observed by Singh (2019); Janju (2021). The cost of cultivation was found significantly affected by the different agroforestry systems being practiced with maximum cost of cultivation (Rs 8,05,658 $ha^{-1}yr^{-1}$) recorded under hortiagriculture system in altitudinal zone-III. The horticultural crops often require more intensive management which includes activities such as regular pruning, irrigation, pest and disease management, fertilization, and harvesting. Labor costs associated with these activities can be substantial. Horticultural crops may require specialized inputs such as specific fertilizers, pesticides, and growth regulators tailored to their needs. These inputs can be more expensive. The horticultural crops mainly the apple is high-value crop, while apple yield higher profits per unit area compared to field crops, the initial investment and ongoing costs associated with their cultivation can also be higher. The results align with the observations made by Singh (2019); Chisanga *et al*. (2013) in the altitudes of Himachal Pradesh. However, among all the agroforestry systems, pastoralsilviculture system resulted in minimum cost of cultivation (Rs 23654 $ha^{-1}yr^{-1}$) due grasses and tress not required any inputs such as fertilizers, pesticides, and herbicides compared to horticultural and field crops. Trees can naturally enhance soil fertility and provide some degree of pest control, reducing the need for external inputs. The tree component in pastoralsilviculture systems help to prevent soil erosion by stabilizing the soil with their root systems and providing canopy cover. This can reduce the need for costly erosion control measures required in conventional crop production. The findings of Sharma (2022), are in line with results of the Shimla district. The cost of cultivation under agroforestry systems in the Shimla district of Himachal Pradesh followed the order hortiagriculture > hortipastoral > hortiagrisilviculture > agrihortsilviculture > agrihorticultre > pastoalsilviculture. Along the different altitudinal zones, the cost of cultivation was found to have increased with the increase in altitude. The various studies (Chisanga *et al*., 2013; Singh, 2019; Sharma *et al*., 2022) also reported the trend of increasing cost of cultivation along altitude in Himachal Pradesh. With increase in altitude often have harsher climates and rugged terrain, which can make cultivation more difficult and expensive in mountainous regions, terracing may be necessary to create flat surfaces for cultivation, which requires significant investment in infrastructure such as retaining walls, irrigation systems, and drainage channels. These structures add to the overall cost of cultivation. Farmers may need to invest in crop varieties that are adapted to the specific conditions of higher elevations, which can be more expensive. Labor costs may be higher at higher elevations due to the challenging working conditions, including steep slopes, thinner air, and colder temperatures. Farmers may need to pay higher wages or provide additional incentives to attract and retain workers. Farmers may need to invest in protective measures such as hail protection systems or insurance coverage to mitigate these risks, adding to the overall cost.

Gross returns data showed in the Table 2 revealed that the prevalent agroforestry systems among the different farmers categories along the altitudinal zones of Shimla district of Himachal Pradesh was found the highest under the semi-medium farmers category (Rs 17,16,875 $ha^{-1}yr^{-1}$) in altitudinal zone-III and lowest under the marginal farmers category (Rs 68,79,721 $ha^{-1}yr^{-1}$) in altitudinal zone-I. Similarly, Net returns was found the highest under the semi-medium farmers category (Rs 10,94,300 $ha^{-1}yr^{-1}$) in altitudinal zone-III and lowest under the marginal farmers category (Rs 3,95,185 $ha^{-1}yr^{-1}$) in altitudinal zone-I (Table 3). The semi-medium categories farmers have more resources, and infrastructure which allow them to produce more and achieve economies of scale. Semi-medium category farmers often have better access to resources such as credit, technology, seeds, fertilizers, and irrigation facilities. These resources enable them to enhance productivity, improve crop yields, and ultimately increase their gross and net income compared to marginal category farmers who may have limited access to these resources. Semi-medium farmers may have more financial capacity to invest in modern farming equipment, technology, and infrastructure improvements, which can lead to increased efficiency and productivity, ultimately resulting in higher gross as well as net incomes. These results consistent with the other researchers (Singh, 2019; Janju, 2021). The gross returns were found significantly affected by the different agroforestry systems being practiced with maximum gross returns (Rs 24,02,464 $ha^{-1}yr^{-1}$) recorded under hortiagriculture system in altitudinal zone-III. Likewise, highest net returns (Rs 15,96,806 $ha^{-1}yr^{-1}$) recorded under hortiagriculture system in altitudinal zone-III of Shimla district of Himachal Pradesh. The horticultural crops typically fetch higher prices in the market compared to crops grown in other agroforestry systems. Horticultural crops harvesting every year allows for more opportunities to generate income compared to crops with longer gestation periods, such as timber or perennial tree crops, which may only be harvested every few years. Farmers engaged in horticulture may have better access to information, training, and technology, enabling them to improve productivity, quality, and market competitiveness, ultimately leading to higher gross as well as net returns. Along the different altitudinal zones, the gross and net returns was found to have increased with the increase in altitude. The overall of gross returns varies from 75,995-24,02,464 Rs $ha^{-1}yr^{-1}$ and net returns ranging between 52,341-15,96,806 Rs $ha^{-1}yr^{-1}$. The various researchers (Chisanga *et al.*, 2013; Singh, 2019; Sharma, 2022) also reported the trend of increasing gross returns and net returns along altitude in Himachal Pradesh. The altitude often leads to cooler temperatures, which can extend the growing season or create more favorable conditions for certain crops mainly for apple, cherry and pear crops. This longer growing season can result in increased yields and higher returns. Higher elevations may receive more precipitation or have access to water sources such as rivers or streams, which are crucial for irrigation. Elevation can influence the prevalence of pests and diseases. Higher elevations may experience fewer pest and disease pressures due to cooler temperatures or other environmental factors, resulting in lower production costs and higher returns. Some crops are better suited to higher elevations due to specific environmental requirements such as cooler temperatures or lower humidity.

Benefit: Cost Ratio data showed in the Table 4 revealed that the prevalent agroforestry systems among the different farmers categories along the altitudinal zones was found the highest under the semi-medium farmers category (2.79) in altitudinal zone-III and lowest under the marginal farmers category (2.39) in altitudinal zone-I of Shimla district of Himachal Pradesh. The semi-medium farmers typically operate on a larger scale than marginal farmers. Semi-medium farmers often have better access to resources such as finance, land, technology, and information compared to marginal farmers. Diversification allows them to spread risks across multiple enterprises, reducing the impact of crop failures or market fluctuations. Additionally, they may have better access to insurance or other risk management tools, further enhancing their resilience and profitability. Semi-medium farmers typically have more financial capacity to invest in their farms compared to marginal farmers. These results consistent with the other researchers (Singh, 2019; Janju, 2021). The Benefit: Cost Ratio were found significantly affected by the different agroforestry systems being practiced with maximum (3.21) recorded under pastoralsilviculture system in altitudinal zone-I of Shimla district of Himachal Pradesh. Pastoralsilviculture diversification can lead to multiple revenue streams, such as income from livestock products (meat, milk, wool) as well as from timber, non-timber forest products, and ecosystem services. In the pastoralsilviculture system grasses and tress not required any inputs such as fertilizers, pesticides, and herbicides compared to horticultural and field crops. Additionally, trees contribute to soil fertility, water retention, and erosion control, thus improving overall land productivity for both forestry and pastoral purposes. Pastoralsilviculture system are often designed with sustainability in mind, balancing economic benefits with environmental and social considerations. Chisanga *et al*. (2013); Singh (2019); Sharma (2022) also reported the trend of decreasing benefit: cost ratio along altitude in Himachal Pradesh.

CONCLUSIONS

The study on the economic productivity of agroforestry systems in Shimla district of Himachal Pradesh reveals that agroforestry offers a sustainable and economically viable land-use option in the mid-hill Himalayan region. Various agroforestry systems such as agri-silviculture, horti-agriculture, agri-horticulture, silvi-pastoral, and agri-silvi-horticulture are practiced by farmers depending on altitude, soil type, and socio-economic conditions. Among these, horti-agriculture systems—especially those integrating apple orchards with vegetable and cereal crops—emerged as the most profitable, generating higher net returns per hectare and favorable benefit-cost ratios. These systems not only diversify farm income but also enhance resource utilization and provide ecological services like soil conservation, moisture retention, and carbon sequestration. Silvi-pastoral and agri-silvicultural systems, although less lucrative in immediate cash returns, were found to contribute significantly to fodder, fuelwood, and livestock support, which indirectly improves household economy and food security. Farmers practicing integrated agroforestry systems reported better income stability, reduced risk of crop failure, and year-round employment opportunities, reducing seasonal outmigration from rural areas. Agroforestry systems in Shimla district offer a promising pathway to sustainable land use and enhanced rural livelihoods. The integration of trees, crops, and livestock contributes not only to increased economic returns but also to long-term environmental stability. The study concludes that: Horti-agriculture systems, particularly apple-based, are the most economically productive in the region. Agroforestry systems improve land productivity, diversify income sources, and ensure better climate resilience. These systems are particularly suitable for hilly terrain, where traditional mono-cropping is limited by ecological constraints. With appropriate policy support, access to technical knowledge, and market linkage, agroforestry can be scaled up to improve the economic well-being of hill farmers and promote climate-resilient agriculture. Hence, the promotion of agroforestry in Shimla and similar agro-climatic zones can play a significant role in achieving sustainable agricultural development and rural economic growth.

FUTURE SCOPE

The future scope of studying the economic productivity of agroforestry systems in Shimla district includes enhancing income through diversified crops and tree species, improving climate resilience, and promoting sustainable land use in hilly areas. Integration of modern technologies, value addition, and policy support can further boost productivity and livelihoods. Agroforestry also holds potential for carbon sequestration, eco-tourism, and long-term environmental sustainability in the region.

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