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Research

Adoption of Traditional Agroforestry Systems and its Socio-Economic Contributions to Farmers in three Districts of Arunachal Pradesh (India), Lying Along Three Altitudinal Gradients

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Abstract:
Arunachal Pradesh, India, has a strong tradition of practicing agroforestry. A comprehensive socio-economic survey was carried out across three elevation ranges: 100 – 700 m above mean sea level (amsl) (Elevation I), 700-1400 m amsl (Elevation II), and 1400-2000 m amsl (Elevation III), located in three different districts of the state: Papum Pare, Lower Subansiri, and Kra Daadi. The households typically consumed seasonal vegetable and grain crops, selling any surplus. The fruit trees, firewood, timber, and other economically important trees were typically interplanted with vegetables and crop plants in a specific area of land. In Elevation I, a farming household earned an average gross income of at least Rs. 85,884 ha -1 Yr -1, followed by Rs. 1,29,512 ha -1 Yr -1 in Elevation III and Rs. 1,54,505 ha -1 Yr -1 in Elevation II. The net returns per household varied from at least Rs. 51,689 ha -1 Yr -1 in Elevation I to Rs. 1,13,954 ha -1 Yr -1 in Elevation III and Rs. 1,15,865 ha -1 Yr -1 in Elevation II. The research also found that raising livestock in traditional agroforestry systems can yield a substantial annual income of 1 lakh rupees or more, contributing significantly to the overall income. The study's findings indicate that traditional agroforestry plays a crucial role in improving the socio-economic status of local farmers. Furthermore, agroforestry offers opportunities for local communities, particularly women and young people.

Keywords: traditional agroforestry, socio-economy, local farmers, Arunachal Pradesh

1. Introduction

The cultivation of major crops is combined with the planting of trees, shrubs, and herbs, as well as the rearing of animals in a single piece of land, in agroforestry (Purwoko *et al*., 2019). Agroforestry systems are well-known for their significant economic value and ecological benefits. Agricultural lands have come under significant pressure to meet the demands of a growing population, resulting in biodiversity loss and deforestation. As a response, the concept of agroforestry, which seeks to maintain a balance between forests and agriculture, has evolved from the ancient tradition of cultivating trees alongside field crops.

The potential of agroforestry lies in its ability to enhance farmers' livelihoods through multiple channels to increase farm production and income, while also contributing to the preservation of beneficial forest functions for ecosystems, such as biodiversity, ecosystem health, soil and water conservation, and carbon storage on land. Moreover, diversified food sources in such systems can potentially strengthen household food security (Duffy *et al*., 2021 and Kiptot *et al*., 2014).

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2. *Study Area and Methodology*

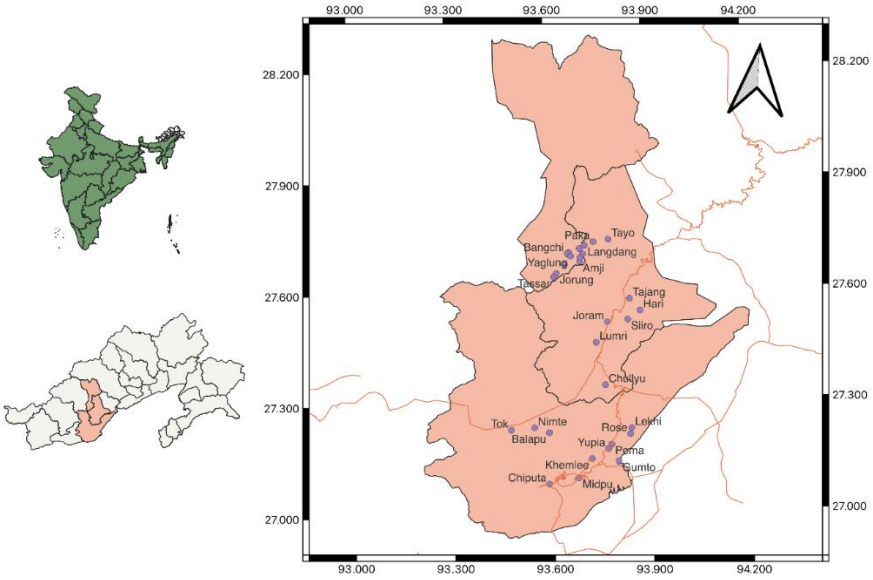

Figure 1 Map representing study sites in the three districts along three different elevational ranges.

The study surveyed the socio-economic parameters of villages at three different elevations: Elevation I (100-700 amsl), Elevation II (700-1400 amsl), and Elevation III (1400-2000 amsl) across the districts of Papum Pare, Lower Subansiri, and Kra Daadi in Arunachal Pradesh.

The map illustrates the study sites located at various elevations (Figure 1).

In every village across the three elevations, ten households were surveyed at random. The Socio-economic parameters considered were

1. **Land holding size and Land use**: Wet rice cultivation, fruit orchards, home garden, kitchen garden, shifting cultivation (Jhum), bamboo grove, area of house, tree plantation etc.
2. **Demography**: Family size, and educational qualification of the family members.

The traditional agroforestry systems (TAFs) of Elevation I, II, and III were analyzed economically by calculating their economic yield. Next, the Gross returns were determined by evaluating the total economic returns based on the current market value of the products obtained from the TAFs. The production cost, encompassing all expenses such as labor, seedlings, fertilizers, pesticides, insecticides, and machinery, was determined to account for the total expenditure involved in producing and maintaining the TAFs. The net return was calculated by subtracting the production cost from the gross return using the formula (Net Return = Gross Return – Production Cost or Input).

The cost-benefit ratio of TAFs was computed, showing the connection between the input cost and the benefits obtained by expressing the ratio as a decimal. This provides an indication of whether the benefits outweigh the costs or the costs outweigh the benefits.

The revenue generated from raising livestock such as pigs, cows, goats, chickens, ducks, etc., was documented individually. Additionally, the income from fish farming was accounted for. This provided insight into the significance of animal husbandry and fishery in the farmers' livelihoods.

3. *Results*

3.1. *Land holding and land use pattern*

The land area is measured in hectares and includes both cultivable areas such as kitchen gardens, home gardens, wet rice cultivation, fruit orchards, jhum, and plantation areas, as well as non-cultivable lands like the area occupied by the house, bamboo groves, and fish ponds. In Table 1, the study documented the land holdings of farmers across all three elevations. Wet rice cultivation had the highest land holdings in Elevation I and Elevation II, with 204.85 ha and 233.06 ha respectively. Elevation III, on the other hand, had the highest land holding for Plantation groves and crops, totalling 167.05 ha. The percentages of land holding, along with the corresponding land sizes, are presented in parentheses in Table 1.

The largest area designated for fruit orchards was observed at Elevation II (120.12 ha), with Elevation III following closely behind (89.25 ha), and Elevation I having the smallest area (65.39 ha). Nearly all farmers across the study sites had bamboo groves, but the largest area (94.53 ha) was found at Elevation III. Home gardens and kitchen gardens were widely used in most households. The largest home garden areas were found in Elevation I (83.60 ha), followed by Elevation III (76.5 ha) and Elevation II (62.25 ha). The kitchen garden areas were relatively similar, typically located in and around the house, covering a few square meters, mainly in the backyard, ranging from 15 to 30 hectares.

Elevation I had the highest reported house area at 181.11 hectares, followed by Elevation II at 62.35 hectares and Elevation III at 46 hectares. The land area for Jhum cultivation was highest in Elevation II at 63.14 hectares, followed by Elevation I at 57.65 hectares and Elevation III at 35.85 hectares. The fish ponds were maintained in a relatively similar range of land area, spanning from 5 to 15 hectares.

Land use	**Land holding (ha)**		
	Elevation I (100-700 m)	**Elevation II (700-1400 m)**	**Elevation III (1400-2000 m)**
Area of house	181.11 (22.94)	62.35 (7.65)	46 (6.8)
Kitchen Garden	28.68 (3.63)	15.78 (1.93)	15.57 (2.3)
Home garden	83.60 (10.59)	62.25 (7.64)	76.50 (11.31)
Wet rice cultivation	204.85 (25.95)	233.06 (28.61)	137.32 (20.3)
Fruit orchard	65.39 (8.28)	120.12 (14.75)	89.25 (13.19)
Bamboo Garden	55.41 (7.01)	68.37 (8.39)	94.53 (13.98)
Jhum cultivation	57.65 (7.3)	63.14 (7.75)	35.85 (5.3)
Plantation trees and crops	104.83 (13.28)	176.74 (21.7)	167.05 (24.7)
Fish Ponds	7.82 (0.99)	12.5 (1.53)	14.22 (2.1)

Table 1. Land holding and utilization pattern at Elevation I, II and III

Note: - Number of households sampled at each elevation was 100

-Values in parenthesis are the percentage of land holding

The study encompassed 10 villages at each elevation, all predominantly practicing TAFs. A total of 10 households were chosen for detailed examination in each village. The family size, including both male and female members, was documented for each household (refer to Table 2). The mean family sizes were 5.75, 6.07, and 5.61 individuals per household for elevations I, II, and III, respectively. Elevation II had the highest number of male and female members, with 304 and 300 individuals, respectively.

Elevation	**Number of villages under study**	**Number of households per village**	**Average family size**	**Male members**	**Female members**
Elevation I	10	10	5.75	304	286
Elevation II	10	10	6.07	315	300
Elevation III	10	10	5.61	305	269

Table 2. Number of villages, households, average family size and number of male and female members in a family

3.2. Age of respondent farmers

The farmers' age groups were divided into three categories: Group A (<35 years), considered as the young age group; Group B (35-55 years), considered as the middle age group; and Group C (>55 years), considered as the old age or near old age group (Figure 2). According to the survey results, the middle-aged group had the highest number of

participants at all three elevations—64% in Elevation I, 51% in Elevation II, and 49% in Elevation III. This indicates that the most active participants practicing TAFs belonged to the middle age group.

The farming activities and decision making were also observed to involve a smaller number of individuals in the younger age group (<35 years) compared to the middle age group. This could be attributed to various reasons, such as many young people leaving rural areas for higher education, jobs in the service industry, or to start businesses in urban areas. As a result, there was a limited participation of younger individuals in farming activities. In Elevation I, II and III, 18%, 27% and 29% of the respondent farmers belonged to this age group, respectively.

The age category of over 55 years also displayed involvement in farming activities, although in smaller numbers compared to the middle-aged group. Age could be a limiting factor for the low participation of people in farming. However, some individuals in this age group had to farm for their daily survival. In Elevation I, II, and III, this age group made up 18%, 22%, and 29% of the farmers surveyed, respectively.

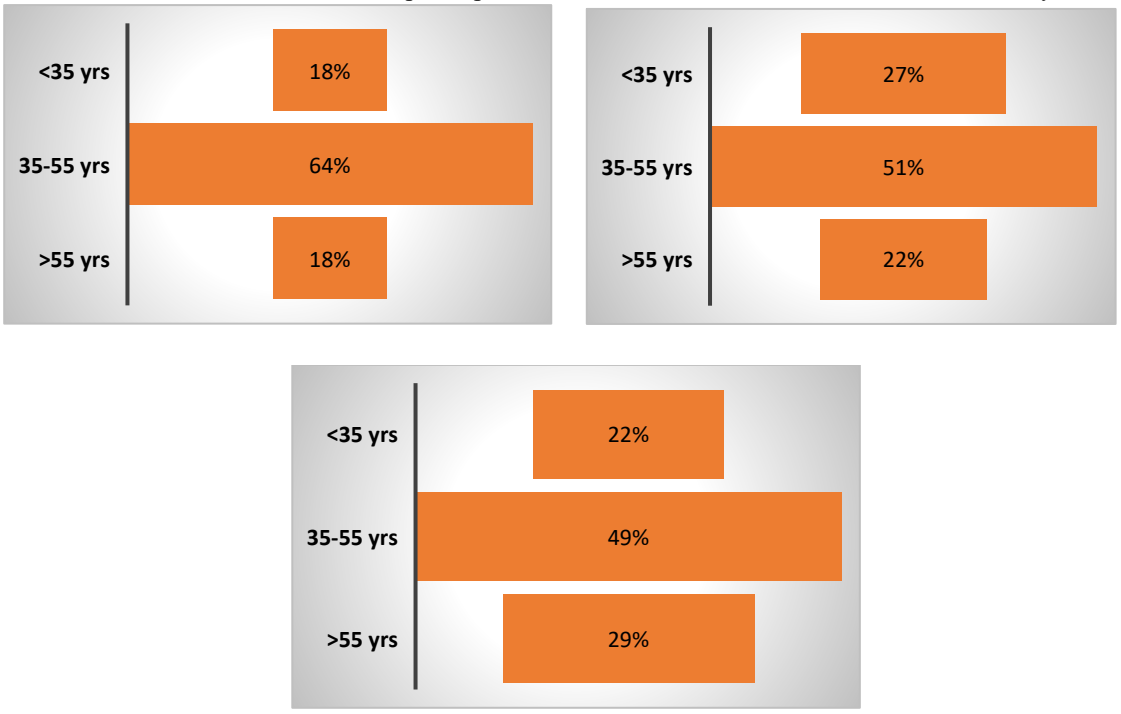

Figure 2 Age group of farmers in the study areas

3.3. Type of house

The study sites categorized the houses as Kutcha, Pucca, and Semi-pucca (Figure 3), which is also a crucial factor in determining a family's status. Houses made of mud, bamboo, and straw are typically referred to as kutcha houses. In Arunachal Pradesh, kutcha houses are predominantly constructed using bamboo and specific types of leaves for building, and these houses are not permanent structures. Pucca houses are durable and enduring residences typically constructed using materials like stone, bricks, cement, concrete, or timber. Semi-pucca houses are partially constructed using materials commonly found in kutcha and pucca houses. Pucca and semi-pucca houses were mostly owned by farmers with good socioeconomic conditions, whereas low-earning farmers typically owned kutcha houses. Figure 3 depicts the distribution of farmers' house types based on elevation. In Elevation I, the proportion of farmers owning pucca houses was the highest at 24%, followed by Elevation III at 16% and Elevation II at 5%. The largest number of semi-pucca houses was owned by farmers in Elevation I, accounting for 45%. Additionally, the highest number of kutcha houses was owned by farmers in Elevation I at 60%, followed by Elevation II at 56% and Elevation III at 31%.

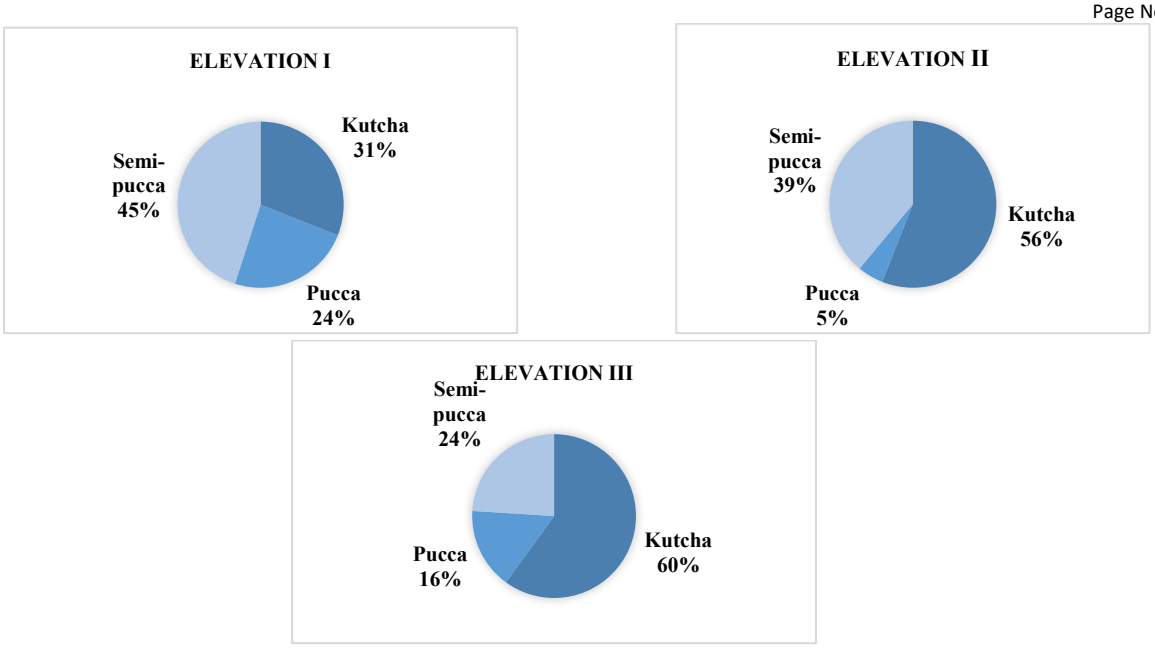

Figure 3 Pie-charts representing the percentage of type of house of farmers in the study areas

3.4. Primary and subsidiary occupation of the respondents

The respondents had diverse job roles, but it was ensured that farming was a significant part of their daily lives. Consequently, they were classified based on their occupations as either farming or non-farming, to determine if farming was their main occupation. Figure 4 illustrates the proportion of primary occupations of respondents engaged in TAFs in Elevation I, II, and III. The information indicated that at each elevation, a greater proportion of households were engaged in farming as their main occupation compared to those involved in other non-farming activities like jobs and businesses. The highest percentage of people engaged in farming as their primary occupation was 75% in elevation III, followed by 69% and 66% in Elevation II and Elevation I respectively. The individuals participating in non-farming activities accounted for 34%, 31%, and 25% in Elevation I, II, and III respectively.

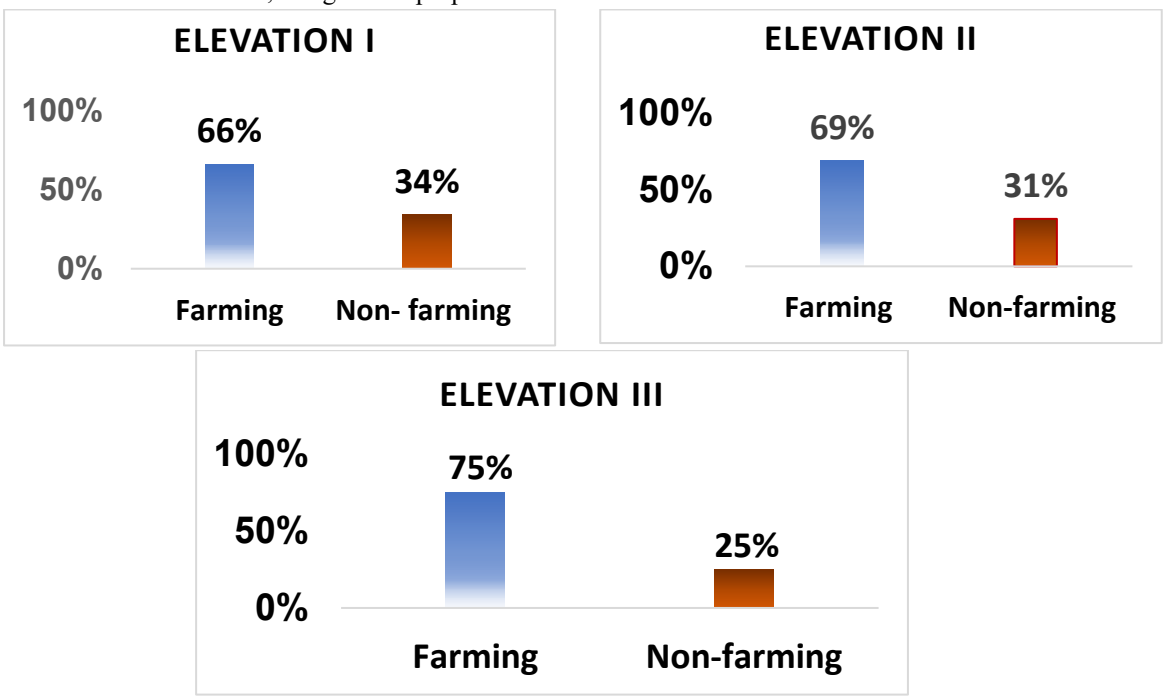

Figure 4 Chart representing the percentage of primary occupation of respondents practicing TAFs

The development of an individual's mindset is strongly influenced by education, which also improves the farmers' ability to manage and make decisions. The educational attainment of farmers and their household members, ranging from illiterate to post-graduate level, was analyzed in Table 3. The highest literacy percentage was observed in Elevation I at 83.62%, followed by Elevation III at 82.84% and Elevation II at 82.12%.

Elevation	**Qualification**							
	Primary	**Middle**	**Secondary**	**Higher Secondary**	**Graduate**	**Post-graduate**	**Illiterate**	**Literacy %**
I	56	63	111	80	151	14	93	83.62
II	60	76	118	106	120	7	109	82.12
III	65	82	102	80	102	18	93	82.84

Table 3. Qualification and literacy percentage of the surveyed villages

3.5. *Economic Analysis*

3.5.1. Gross return

Table 4 recorded the gross returns of TAFs for Elevation I, II, and III. Within Elevation I, gross returns varied from Rs 5,41,000 ha^{-1} Yr^{-1} to Rs 12,31,000 ha^{-1} Yr^{-1}. Elevation II saw gross returns ranging from Rs 9,36,00 ha^{-1} Yr^{-1} to Rs 29,24,000 ha^{-1} Yr^{-1}, while Elevation III had gross returns ranging from Rs 8,06,000 ha^{-1} Yr^{-1} to Rs 15,67,000 ha^{-1} Yr^{-1}. The mean gross returns were Rs 8,58,840 ha^{-1} Yr^{-1}, Rs 15,45,055 ha^{-1} Yr^{-1} and Rs 12,95,129 ha^{-1} Yr^{-1} for TAFs of Elevation I, II and III respectively.

Elevation I	**Gross returns (in INR)**	**Elevation II**	**Gross returns (in INR)**	**Elevation III**	**Gross returns (in INR)**
Balapu	8,94,000	Bangchi	10,43,250	Amji	15,63,040
Chiputa	9,60,000	Bangte	9,36,000	Bokam	12,24,100
Gumto	12,31,000	Bojo	12,37,000	Dui	13,65,000
Khemlee	8,26,400	Chullyu	29,24,000	Hari	8,87,500
Lekhi	7,40,000	Joram	10,55,000	Paka	15,67,000
Midpu	5,41,000	Jorung	12,40,000	Siiro	13,15,000
Poma	11,76,000	Langdang	18,93,000	Tajang	11,17,500
Rose	8,41,000	Lumri	16,41,000	Tassar	15,65,000
Tok	7,74,000	Nimte	12,30,800	Tayo	8,06,000
Yupia	6,05,000	Pania	22,50,500	Yaglung	15,41,150
Mean	8,58,840	***Mean***	15,45,055	***Mean***	12,95,129
Per household	**85,884**	***Per household***	**1,54,505**	***Per household***	**1,29,512**

Table 4. Gross returns (Rs $ha^{-1}Yr^{-1}$) from TAFs in the study areas

3.5.2. Total expenses (Input cost)

The labor charges were either calculated per person or in batches involving local church youth, Self Help Groups (SHGs), and the like. The expenses for maintenance encompassed the costs for weeding, ploughing, clearing the bushes, and maintaining the fences, among others. The overall expenses and input costs covered labor charges, maintenance expenses, expenditures on manure, fertilizers, and pesticides, the purchase or rental of equipment, as well as the costs of seeds or seedlings. When it came to manures, fertilizers, and pesticides, farmers considered both organic and chemical products. The equipment commonly used on the farms included tractors, power tillers, and grass cutters. They obtained seeds/seedlings either from the market or from neighboring farmers with large nurseries. Some farmers received government-subsidized seedlings for important trees and crops, while others prepared their own seedlings for the upcoming sowing season.

Table 5 displays the data on total expenses or input cost in TAFs within the study area. Within Elevation I, the total cost varied from Rs 2,22,200 ha^{-1} Yr^{-1} to Rs 4,97,000 ha^{-1} Yr^{-1}. Additionally, the total cost ranged from Rs 1,61,700 ha^{-1} Yr^{-1} to Rs 8,86,350 ha^{-1} Yr^{-1}, and from Rs 1,14,200 ha^{-1} Yr^{-1} to Rs 1,87,100 ha^{-1} Yr^{-1} in Elevation I and II, respectively.

Elevation III had the highest mean total expenses incurred, totalling Rs 15,55,850 ha^{-1} Yr^{-1}, followed by Elevation II with Rs 3,86,405 ha^{-1} Yr^{-1}

and Elevation I with Rs 3,41,950 ha^{-1} Yr^{-1}. The average total expenses per household in each elevation showed that Elevation I incurred an average cost of Rs. 34,195, Elevation II incurred Rs. 38,840 per household, and Elevation III incurred Rs. 15,585 per household.

Elevation I	**Input cost (In INR)**	**Elevation II**	**Input cost (In INR)**	**Elevation III**	**Input cost (In INR)**
Balapu	3,21,500	Bangchi	1,92,000	Amji	1,54,500
Chiputa	4,61,000	Bangte	1,61,700	Bokam	1,47,500
Gumto	4,97,000	Bojo	53,500	Dui	1,70,500
Khemlee	2,86,000	Chullyu	8,86,350	Hari	1,14,200
Lekhi	3,37,200	Joram	2,54,000	Paka	1,19,900
Midpu	2,22,200	Jorung	3,46,000	Siiro	1,86,500
Poma	3,04,400	Langdang	3,44,000	Tajang	1,33,900
Rose	2,73,700	Lumri	4,89,000	Tassar	1,87,100
Tok	2,81,500	Nimte	3,64,000	Tayo	1,62,500
Yupia	4,35,000	Pania	7,73,500	Yaglung	1,79,250
Mean	3,41,950	***Mean***	3,86,405	***Mean***	1,55,850
Per household	**34,195**	***Per household***	**38,840**	***Per household***	**15,585**

Table 5. Total expenses (Input cost) (Rs $ha^{-1}Yr^{-1}$) in TAFs of the study sites

3.5.3. Net Returns

The net return represents the overall revenue generated by farms and farm products after subtracting the production costs, which is equivalent to the gross income minus the total expenses. The results from Table 6 show that the highest net return from TAFs was observed in Elevation II, with an average value of Rs 11,58,650 ha^{-1} yr^{-1}, and Rs 11,39,544 ha^{-1} yr^{-1} in Elevation III. These figures were significantly higher than the mean net return obtained at Elevation I. The average total net return in Elevation I varied from Rs 1,70,000 ha^{-1} yr^{-1} to Rs 8,71,600 ha^{-1} yr^{-1}, while it ranged from Rs 7,74,300 ha^{-1} yr^{-1} to Rs 20,37,650 ha^{-1} yr^{-1} in Elevation II and from Rs 6,43,500 ha^{-1} yr^{-1} to Rs 14,47,100 ha^{-1} yr^{-1} in Elevation III. The average net return per household in Elevation I amounted to Rs. 51,689, whereas it stood at Rs. 1,15,865 in Elevation II and at Rs. 1,13,954 in Elevation III.

Elevation I	**Net return (In INR)**	**Elevation II**	**Net return (In INR)**	**Elevation III**	**Net return (In INR)**
Balapu	5,72,500	Bangchi	8,51,250	Amji	14,08,540
Chiputa	4,99,000	Bangte	7,74,300	Bokam	10,76,600
Gumto	7,34,000	Bojo	11,83,500	Dui	11,94,500
Khemlee	5,40,400	Chullyu	20,37,650	Hari	7,73,300
Lekhi	4,02,800	Joram	8,01,000	Paka	14,47,100
Midpu	3,18,800	Jorung	8,94,000	Siiro	11,28,500
Poma	8,71,600	Langdang	15,49,000	Tajang	9,83,600
Rose	5,67,300	Lumri	11,52,000	Tassar	13,77,900
Tok	4,92,500	Nimte	8,66,800	Tayo	6,43,500
Yupia	1,70,000	Pania	14,77,000	Yaglung	13,61,900
Mean	5,16,890	***Mean***	11,58,650	***Mean***	11,39,544
Per household	**51,689**	***Per household***	**1,15,865**	***Per household***	**1,13,954**

Table 6. Net returns (Rs $ha^{-1}Yr^{-1}$) from the TAFs at Elevations I, II and III

3.5.4. Cost-benefit ratio of TAFs

The data presented in Table 7 shows that Elevation III had the highest benefit-cost ratio, with a mean value of 8.45, followed by Elevation II at 6.04, and Elevation I at 2.58, indicating higher cost effectiveness with a higher benefit-cost ratio. In Elevation I, the cost-benefit ratio ranged from 1.39 to 3.86. Elevation II had the highest and lowest benefit-cost ratios of 23.12 and 2.90, respectively. For Elevation III, the benefit-cost ratio ranged from 13.06 to 4.96.

Elevation I	BCR	Elevation II	BCR	Elevation III	BCR
Balapu	2.78	Bangchi	5.43	Amji	10.11
Chiputa	2.08	Bangte	5.78	Bokam	8.29
Gumto	2.47	Bojo	23.12	Dui	8.00
Khemlee	2.88	Chullyu	3.29	Hari	7.77
Lekhi	2.19	Joram	4.15	Paka	13.06
Midpu	2.43	Jorung	3.58	Siiro	7.05
Poma	3.86	Langdang	5.50	Tajang	8.34
Rose	3.07	Lumri	3.35	Tassar	8.36
Tok	2.74	Nimte	3.38	Tayo	4.96
Yupia	1.39	Pania	2.90	Yaglung	8.59
Mean	**2.58**	***Mean***	**6.04**	***Mean***	**8.45**

Table 7. Benefit-cost ratio (BCR) of TAFs at Elevation I, II and III

3.6. Annual income from livestock

In addition to maintaining TAFs, the farmers engaged in animal husbandry and fish farming, which were also crucial for supporting their daily livelihood. The animals were primarily raised to meet their protein needs through meat consumption, as well as to assist with farming tasks and generate significant income. The most prevalent animals raised were cattle, swine, goats, poultry, ducks, and pigeons. Fish farming was also widespread, often maintained in separate fish ponds or in conjunction with rice cultivation, known as rice-cum-fish farming. All of these animals provided significant benefits to the farmers by meeting the protein needs of their households and contributing to their income. Figures 5, 6, and 7 depict the income status from livestock in Elevations I, II, and III.

Elevation I showed that the highest income was generated by Pigs earning at least Rs 40,000 to 1 lakh rupees or more annually, surpassing the income of other livestock. This trend was similarly observed in elevations II and III, where pigs earned the highest income, ranging from Rs 80,000 to Rs 1 lakh or above, and Rs 10,000 to Rs 1 lakh or above, respectively. These findings indicate the strong preference for pigs as a livestock by the local farmers. Additionally, pork was a favored meat, following beef, among the local residents, and pigs were identified as important sacrificial animals during local indigenous festivals and marriage ceremonies.

In general, the data indicates that raising livestock is closely linked to the cultivation of trees and crops, which significantly supports the local residents' livelihood. The sale of livestock contributes substantially to the total income. Fish farming was less prevalent at Elevation I compared to Elevation II and III.

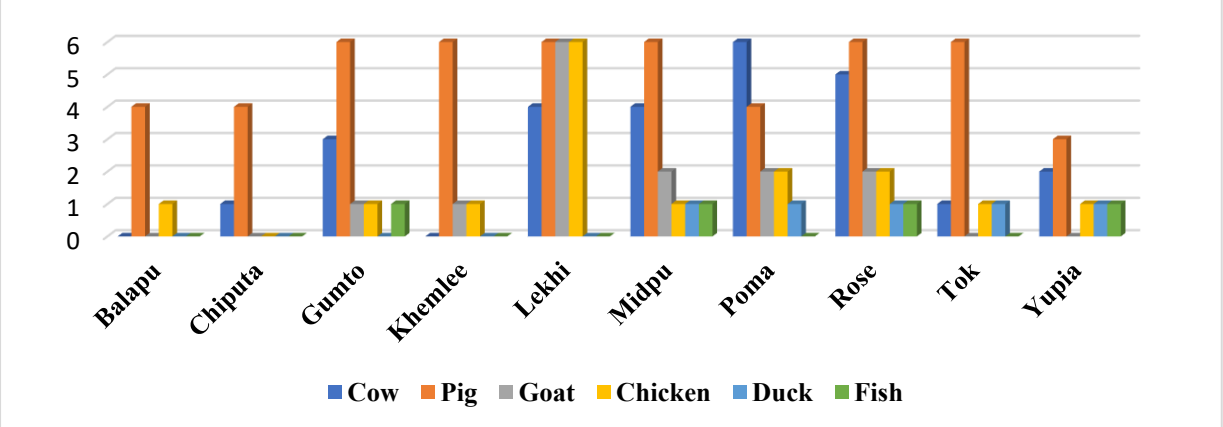

Figure 5 Income from livestock and fishery in Elevation I

Note: The figures/codes 0 to 6 represent various income ranges as follows: 0 signifies an income of 0 (Zero), 1 represents an income range between 1 to 20,000, 2 corresponds to an income range between 21,000 to 40,000, 3 denotes an income range of 41,000 to 60,000, 4 indicates an income range of 61,000 to 80,000, 5 signifies an income range of 81,000 to 1,00,000, and 6 is for an income range of 1 lakh and above.

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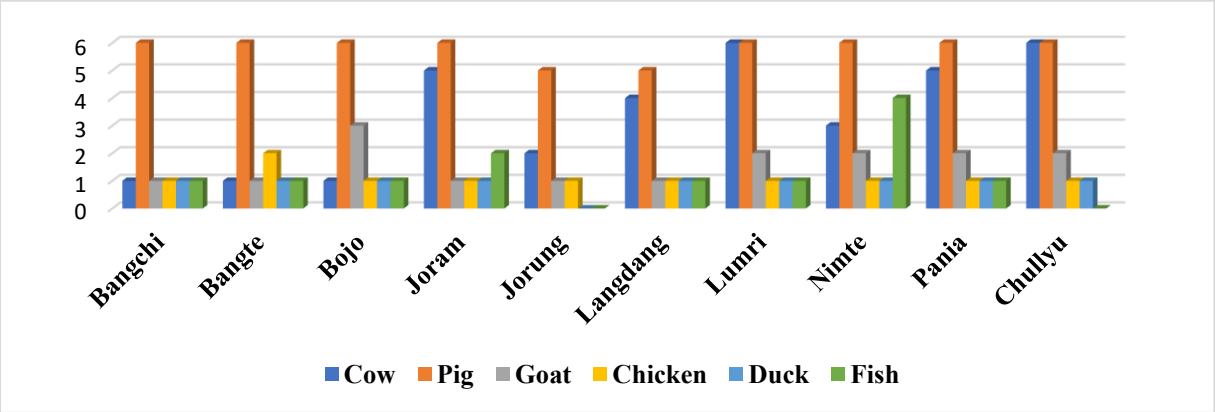

Figure 6 Income from livestock and fishery in Elevation II

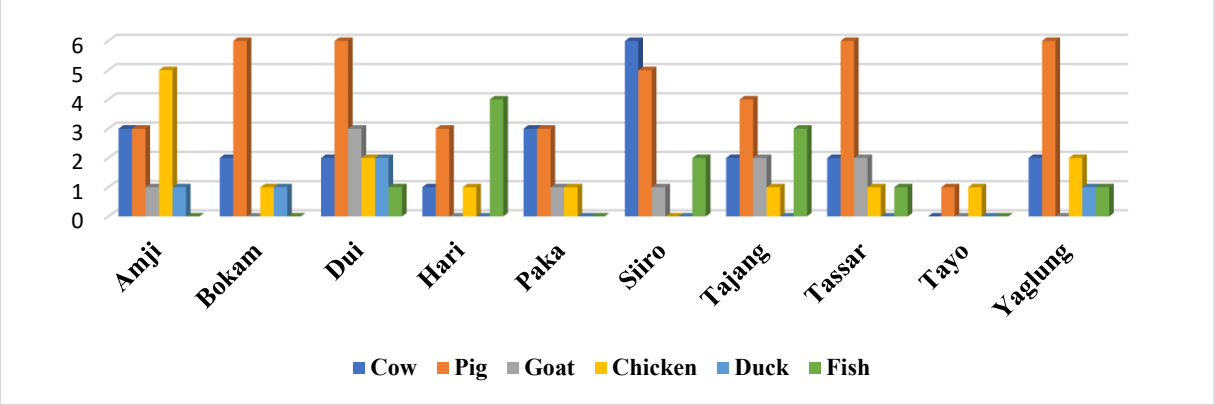

Figure 7 Income from livestock and fishery in Elevation III

4. Discussion

The socio-economic and livelihood role of traditional agroforestry (TAFs) in Arunachal Pradesh was documented in the current research. In a study conducted by Dwivedi et al. (2007) in western Uttar Pradesh, the primary driver of TAFs practice was investigated, with fuelwood and additional income identified as the key factors. While traditional agroforestry may appear less appealing compared to commercial agroforestry, it was found to be significant for the farmers' livelihood. The size and distribution of land holdings are being carefully studied, as they provide insight into how frequently the land was used for farming and whether TAFs and monoculture farming were practiced. In Table 1, we can observe the distribution of land and its usage across elevation I, II, and III. Singh (2014) illustrated the land usage patterns in the Giri catchment of Himachal Pradesh. The average values were lower compared to the findings in our current study. Thakur et al. (2018) conducted research in Giridh district, Jharkhand, revealing that 76.88% of the land was utilized for agroforestry, 42.49% for horticulture, and 22.50% for bamboo cultivation.

In the designated piece of land, a few specific fruit trees were consistently cultivated, accompanied by the intercropping of seasonal vegetables and cereal crops. These crops were mainly used for family consumption, with any surplus being sold. Each altitude level was known for its particular economically significant fruit trees. For example, at Elevation I, trees like *P. guajava*, *C. nucifera*, *A. comosus*, *A. heterophyllus, L. chinensis*, etc. were prevalent, while at Elevation II, *Citrus x sinensis*, *A. comosus*, *M. zapota*, *Musa* sp., etc. were common. Elevation III was distinguished by the popularity of *Citrus x sinensis*, *P. domestica*, *Fragaria x ananassa*, and *A. deliciosa*. The main source of income was generally attributed to the fruit trees and cash crops. The TAFs contained a significant number of trees, particularly for providing shade, timber, and firewood. Tall trees in the gardens provided excellent shade for cash crops such as *A. subulatum*, *Z. officinale*, and others. Most of the trees were not deliberately planted but were preserved from the original forest state before being cleared for agricultural purposes, particularly in the hilly temperate regions of Elevation II and III. According to a study by Sundriyal et al. (1994), crop productivity was mostly unaffected by elevational range and climatic conditions but was largely

dependent on input range and the fertility of the land from farm to farm.

Education has a significant impact on the socio-economic status of a family. Higher education qualifications are linked to higher earnings. Individuals with a good education have the knowledge and skills to handle and address matters in a professional manner. This also applies to farmers who are well-educated. The current research reveals that individuals with no literacy skills had limited knowledge about modern farming methods and relied primarily on traditional farming practices that have been used for generations. However, educated farmers demonstrated an interest in improving their agricultural expertise through advanced knowledge and technology. Literacy levels were 80% or higher in all study locations (Elevation I, II, and III).

In the study areas, the TAFs showed high gross and net returns. It's worth noting that the gross returns encompassed income from all tree and crop cultivation systems, while income from livestock was generated and represented independently. In the areas under study, the average gross income ranged from Rs. 8,58,840 to 12,95,129 per hectare per year. Additionally, the net returns were also substantial, varying from Rs. 1,55,585 per hectare per year to 11,39,544 per hectare per year. The average gross earning per household in the study sites was also analyzed. In Elevation I, a farming household earned at least Rs. 85,884 per hectare per year, followed by Rs. 1,29,512 per hectare per year in Elevation III and Rs. 1,54,505 per hectare per year in Elevation II. The calculated net returns per household varied, with a farming household in Elevation I earning at least Rs. 51,689 ha $^{-1}$ Yr -^{1}, while in Elevation III the earnings were Rs. 1,13,954 ha $^{-1}$ Yr $^{-1}$, and in Elevation II, they were Rs. 1,15,865 ha $^{-1}$ Yr $^{-1}$.

In Kullu valley of Himachal Pradesh, Rajput (2010) documented that agri-horticulture systems yielded very high returns of Rs. 7.32 lakhs/ha/year, while silvi-pasture systems produced returns of 0.70 lakh/ha/year. Additionally, Singh (2014) stated that the mean maximum net returns from agri-silviculture, agri-silvi-horticulture, and agri-horti-silviculture were Rs 2,77,415 per ha/year, Rs 2,70,747 per ha/year, and Rs 13,150 per ha/year, respectively. The highest total expenses (input costs) were incurred in Elevation III, amounting to Rs 15,55,850 ha^{-1} Yr^{-1}, followed by Rs 3,86,405 ha^{-1} Yr^{-1} and Rs 3,41,950 ha^{-1} Yr^{-1} in Elevation II and I, respectively. In the current research, the TAFs demonstrated a cost-benefit ratio ranging from 2.58 in Elevtion I, 6.04 in elevation II to 8.54 in Elevation III, showing an increasing trend. According to Singh (2014), the cost-benefit ratio decreased in the following order: agri-silvi-horticulture (2.38) > agri-horti-silviculture (2.17) > agri-horti-culture (1.87). In a study by Rajput (2010) in the Kullu valley of Himachal Pradesh, a cost-benefit ratio of 2.94 was reported for agri-horti-culture.

Verma et al. (2002) reported a cost-benefit ratio of 1.99 to 2.34 for agri-silvi-horticulture systems in Solan, Himachal Pradesh. In Sikkim, Sharma et al. 2007 found a cost-benefit ratio ranging from 1.87 to 5.7 for cardamom-based TAFs, while Bhatt and Mishra (2003) reported a ratio of 1.87 to 5.7 for Assam lemon and Guava-based agroforestry systems in Meghalaya. The current study also highlighted significant income generated from livestock rearing in conjunction with the practice of TAFs, with annual income exceeding 1 lakh, as depicted in Figures 5, 6, and 7. The study areas showed that the farmers' socio-economic status was satisfactory, indicating that the adoption of agroforestry played a significant role. Farmers with higher incomes were more resilient to shocks compared to those with lower earnings (Nigussie et al., 2020; Teshager Abeje et al., 2019). Additionally, agroforestry created opportunities for indigenous people, particularly women and youths, aligning with the research by Hanif et al. (2018).

5. Conclusions

Based on the present research, TAFs supported a wide range of crops, fruit trees, wood and fuelwood, medicinal and ornamental trees, along with other economically important trees. TAFs have a considerable impact on local communities, especially those in rural areas, by generating significant gross revenue and net returns.

Most farmers depend on TAFs to fulfill both their daily food requirements and their income-generating needs. The growth of fruit trees and cash crops was found to contribute the most to their income. The majority of farmers practiced organic farming, enabling them to consume healthy food and preserve the soil on their fields, thereby ensuring the sustainability of the farms. The residents of native Arunachal Pradesh are still not very familiar with the concept of agroforestry, even though they often practice traditional, less intensive agroforestry. In the past, people used to search for food in the wild before creating a few conventional methods to support their way of life. Traditional agroforestry is a system that

can fulfill the productivity, sustainability, and adaptation requirements of the community's traditional farmers.

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