

RESEARCH ARTICLE

ENHANCING RURAL LIVELIHOODS THROUGH AGRO-BIODIVERSITY CONSERVATION, SUSTAINABLE AGRICULTURE, AND HOMESTAY TOURISM IN THE TONS RIVER BASIN, GARHWAL HIMALAYA

Vishwambhar Prasad Sati^{a*}, Kiran Tripathi^b, Rajesh Bhatt^c, Manju Bhandari^d, Kamlesh Kumar^e, Surajit Banerjee^a

^aDepartment Of Geography And Resource Management, Mizoram University, Aizawl, India.

^bDepartment Of Geography, Govt. Degree College, Bhupatwala, Haridwar, India.

^cDepartment Of Geography, Govt. Degree College, Nagnath Pokhari, India.

^dDepartment Of Geography, Govt. Degree College, Dehradun Shahar, India.

^eGeographical Society Of Central Himalaya, Dehradun, India.

*Corresponding Author: vpsati@mzu.edu.in

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ABSTRACT

The Tons River basin's traditional farming practices yield minimal output despite a favourable agro-climate that supports high crop production and productivity. This paper explores how agro-biodiversity conservation, sustainable agriculture, livestock farming, and homestay tourism can improve rural livelihoods in the Tons River basin. Based on empirical research from field surveys and personal observations, this study examines five villages in the basin, surveying 50 households (10 from each village) through purposive sampling, with heads of households participating. The average age of respondents was 45 years, and all were literate. The study reveals that the Tons River basin boasts rich agro-biodiversity, with 47 crop races/cultivars cultivated across the five villages. The basin is divided into four agro-climatic regions—subtropical, sub-temperate, temperate, and cold—with major crops including mango, tomato, apple, pear, peach, plum, apricot, walnut, red rice, millets, Fafara, Manduwa, potato, and Rajma, each featuring numerous races/cultivars. Meanwhile, the agriculture is practiced traditionally, which production is insufficient to feed the increasing population. The scope of sustainable agriculture through the cultivation of fruits and vegetables, and homestay tourism in enhancing rural livelihood is immense. The study concludes that enhancing livelihoods in the basin can be achieved through the conservation of agro-biodiversity, adoption of sustainable agriculture practices, development of livestock farming, and promotion of homestay tourism, as these strategies align well with the region's characteristics.

KEYWORD

Rural livelihood; Agro-biodiversity; Sustainable agriculture; Livestock farming; Homestay tourism; Tons River basin.

1. INTRODUCTION

The integration of agro-biodiversity conservation, sustainable agriculture, rural tourism, and livelihood enhancement aims to foster holistic rural development by promoting environmental sustainability, economic resilience, and social well-being (Sati, 2017). This comprehensive approach addresses multiple facets of rural development. Agro-biodiversity encompasses the variety of crop races and cultivars grown in agricultural fields, which is crucial for enhancing crop productivity, soil health, and ecosystem resilience (Altieri, 1999; Jarvis et al., 2007). Sustainable agriculture involves adopting farming practices suited to the agro-climate and crop suitability, thereby integrating environmental health with economic profitability (Pretty, 2008; Tilman, 2002). Livelihood enhancement focuses on improving crop production and productivity as well as the economic and social development of rural communities. Strategies for sustainable livelihoods include skill development, market access, and diversification of farming systems (Chambers and Conway, 1992; Ellis, 2000). Homestay tourism has emerged as a significant income source in rural areas. Farming communities are increasingly offering homestays to tourists, which

supports sustainable livelihoods. In addition to providing traditional food and beverages, rural hosts engage in folklore performances and cultural exchanges (Lane, 1994; Roberts and Hall, 2001). Collectively, these components contribute to environmental, economic, and social benefits, enhancing food security and reducing poverty (Sati, 2014).

The Himalayan economy is largely primitive and relies on traditional agricultural practices, leading to its classification as an agricultural economy. Approximately 70% of the population resides in rural areas and engages in traditional farming. However, crop production and productivity are low, often failing to meet the basic needs of rural populations (Sati, 2023). Despite this, the Himalaya is rich in agro-biodiversity, with a variety of crop cultivars grown on the same land through the Barahnaja system (Sati, 2023). The potential for growing diverse crops, from cash crops to millets and subsistence crops, is significant. The region's agro-climate is divided into four zones—subtropical, subtemperate, temperate, and cold—each with its unique characteristics, leading to variations in farming systems.

Unlike other mountainous regions globally, where diverse livelihood options contribute to sustainable rural communities, the Himalayan

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region has yet to achieve similar progress. For comparison, Yunnan Province in China, once the poorest province with 442,000 people living below the poverty line, has eradicated poverty by 2024 through intensive horticultural cultivation (Institute of Security and Development Policy, 2024). Similarly, the Andes Mountains in South America have achieved food security through the cultivation of cash crops and the adoption of climate-smart agriculture (Gustavo, 2017). In Europe, the Alps benefit from a diverse agro-climate that has boosted dairy farming and the cultivation of cash crops, including fruits and vegetables (Jongeneel et al., 2023).

The Tons River basin, situated in the Garhwal Himalaya, is one of the most spectacular and rich regions in natural capitals including agro-biodiversity. However, it is also one of the most fragile landscapes and the remotest areas of the Himalaya. The local livelihood relies heavily on the cultivation of traditional crops, which primarily supports subsistence farming, with minimal output. Rural settlements are often isolated, lacking transportation infrastructure, necessitating long walks for access to markets. Additionally, surplus products cannot be sold due to inadequate market facilities and the absence of cold storage. Consequently, the residents face severe living conditions and critical economic challenges. However, the basin presents several potential livelihood opportunities, including the cultivation of fruits, vegetables, spices, and important food grains, thanks to its diverse altitudinal zones that support a variety of crops. Moreover, livestock farming and homestay tourism offer significant potential for enhancing the livelihoods of the Tons River basin's inhabitants.

While numerous studies have explored various livelihood issues in mountainous regions globally and specifically in the Himalaya, the Tons River basin has been largely overlooked. This may be due to its remoteness and lack of educational institutions. This study is unique and pioneering in its focus on this region. Utilizing data from field surveys and participatory

observation, this research is purely empirical. The primary research question addressed was how to enhance livelihoods given the rich agro-climate and poor infrastructural facilities of the Tons River basin. The study aims to achieve this by focusing on the conservation of agro-biodiversity, the practice of sustainable agriculture, and the promotion of livestock farming and homestay tourism. We hypothesize that these strategies—agro-biodiversity conservation, sustainable agriculture, and the development of livestock farming and homestay tourism—will generate income and significantly improve livelihoods in the Tons River basin. This research will be very useful for the sustainable livelihoods in the Tons River basin and similar other areas of the Himalaya where the similar landscape and climate prevail.

2. STUDY AREA

The Tons River is a significant tributary of the Yamuna River, part of the Ganges system. Originating from the Bandarpunch Mountain at 6,385 meters in Uttarkashi District, Garhwal Himalaya, India, it flows into the Yamuna River at Kalsi. The river stretches 148 kilometers and has a catchment area of 5,146 square kilometers. The Tons River is formed at Netwad, Uttarkashi District, where its two main tributaries, the Rupin and Supin, converge. The region also hosts the Netwad-Mori hydropower project. Another notable tributary is the Pabbar River. The Tons River primarily drains the Uttarkashi District, forming a natural border with Himachal Pradesh (Figure 1). The Tons River basin is characterized by its fragile ecosystems and rugged landscapes, frequently experiencing landslides, mass movements, flash floods, and debris flows. As a glacial-fed river, the Tons River maintains high water volume and velocity year-round. The basin is culturally rich, with three distinct sub-cultural realms: Jaunsar-Babar, Rawain, and Garhwal. It features a diverse landscape and a range of climatic conditions, from subtropical humid to sub-temperate, temperate, cold, and frigid cold.

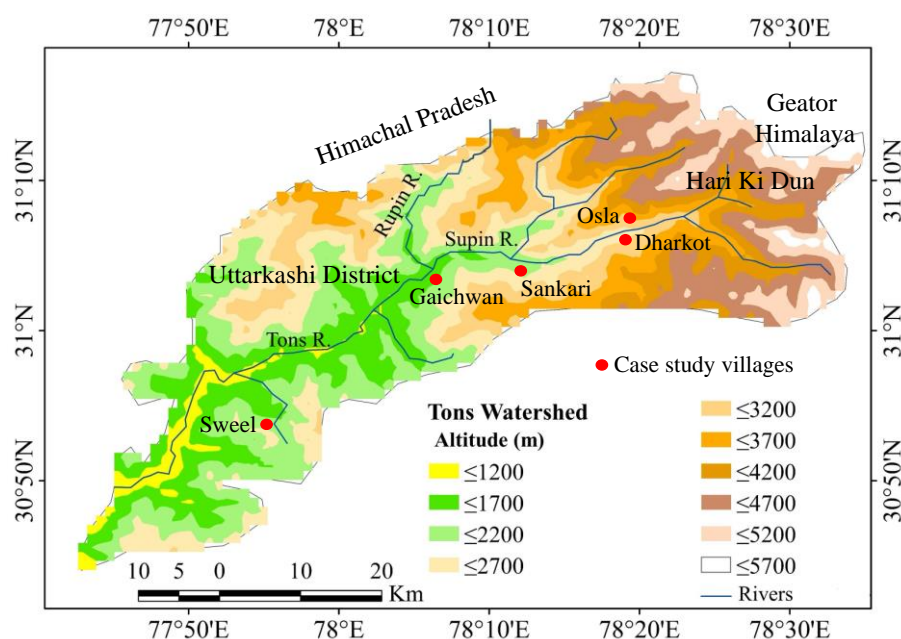


Figure 1: The Tons River basin showing case study villages

The Kamal River valley, located in Purola Taluk, is a fertile and crucial agro-climatic region often referred to as a lifeline for the local population. This valley is renowned for its production of red rice, which is cultivated with high yields. Fishing also serves as an important livelihood option for residents. Within the valley, Rama Sarain stands out for its exceptional rice productivity, supported by irrigated land. The Supin River catchment, also known as Shiktar Patti, is noted for the high production of apples, pears, potatoes, Rajma, as well as various vegetables, fruits, pulses, and grains. Our study focuses on several villages: Sweel, located in the Kamal Valley, is known for large-scale tomato cultivation; Gaichwan, situated in the Tons Valley, is recognized for its high-quality and abundant apples; and Sankari, Dharkot, and Osla, which lie in the Supin Valley, are noted for their abundant production of apples, potatoes, and Rajma. These villages, ranging in altitude from 1,300 to 2,750 meters, exhibit rich agro-biodiversity (Table 1). However, infrastructural facilities are severely lacking. While some villages are situated along roadsides, road conditions deteriorate significantly during the monsoon and post-monsoon periods. Educational institutions are sparse, and market facilities are inadequate, compounding the challenges faced by these rural communities.

Table 1: Geographical information of the selected case study villages

Village	Location	Altitude (m)	Accessibility from road
Sweel	Kamal valley	1300	1.5 km
Gaichwan	Tons valley	1500	On the road
Sankari	Supin valley	1940	On the road*
Dharkot	Supin valley	2530	On the road*
Osla	Supin valley	2750	8 km

*Road condition is worst. During rainy and post rainy seasons, road remains blocked.

Figure 2 illustrates four case study settlements situated along the Kamal River, Tons River, and Supin River. The agro-climate in these areas is diverse, varying with altitude, and supports the cultivation of numerous crop races and cultivars, with some crops achieving high production and

productivity. Gangad village is known for its large-scale production of Rajma and potatoes, a trend also seen in Dharkot village. Gaichwan village

stands out for its high apple and pear production, while Sweel village is noted for its abundant potato yields.

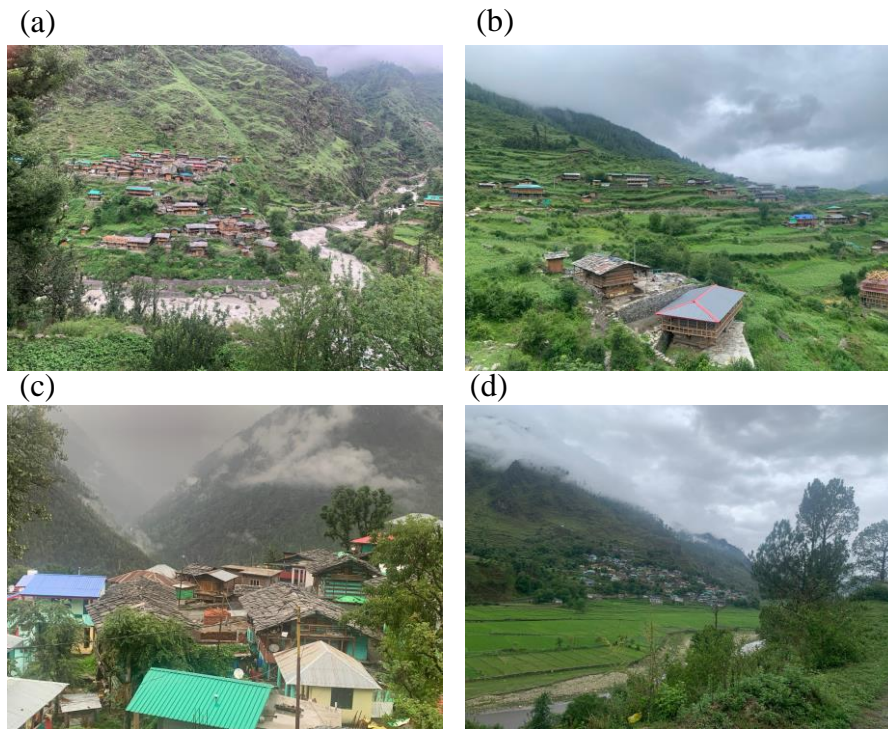


Figure 2: Rural settlements from upper Supin basin to lower basin surrounded by agricultural fields (a) Gangad village (b) Dharkot village (c) Gaichwan village (d) Sweel village. Photo by: Vishwambhar Prasad Sati

The houses are made of wood mainly deodar (coniferous tree). This region is rich in floral diversity. Forest types vary from subtropical to subtemperate and temperate and all these have high economic value. The high altitudinal regions above 3000 meters possess alpine pasturelands that remain open during the summer. In winter, these pasturelands are snow-capped. A variety of flowers and medicinal plants grow in these pasturelands, among which Hari Ki Dun and Kedar Kantha are prominent.

3. DATA COLLECTION AND SURVEY METHODS

This study primarily employed field surveys, focusing on a case study of five villages with household-level data collection. We surveyed 50 households, with 10 households from each village. The selection of villages was based on factors such as altitude, distance from the road, and crop types. Households were chosen using a purposive random sampling method. A structured questionnaire was developed to gather information from the head of each household on various aspects, including the number and types of crops grown, the area and production of each crop, irrigation practices, annual income from each crop, government subsidies, and market facilities. The average age of respondents was 45 years, and all were literate.

In addition to crop-related questions, the survey addressed other livelihood options. For livestock farming, questions covered the types and number of livestock, production of milk, meat, and wool, and income generated from these products. For homestay tourism, we inquired about the number of rooms available for guests, the facilities provided, the number of tourists staying annually, and income earned from homestays. Farmers were also interviewed about market facilities and the challenges they face in agriculture and selling their crop products.

The collected data were analyzed and processed to assess various aspects of crop cultivation and livelihood in the case study villages. We compiled a list of different crops grown, including their local, English, and scientific names. Agro-climatic zones were identified based on the crops grown in each village and their respective altitudes. We analyzed crop-specific data, including the area, production, and productivity for each village. Crops were ranked based on their productivity and suitability for different locations and altitudes.

A key aspect of the analysis was the economic valuation of principal crops. We calculated the total value of crop production by multiplying the amount produced by the market rate of each crop. The total value was then converted into USD for each household, allowing us to rank the economic contribution of each crop.

Additionally, we evaluated the role of livestock and homestay tourism in enhancing livelihoods. Government support in agriculture, such as pruning, fertilizers, and pesticides, along with the physical labour provided by farmers, contributes significantly to the benefits derived from crop production. A base map was created from satellite imagery, depicting two-dimensional landscapes that include rivers, agro-climatic zones, and land use.

4. RESULTS

4.1 Enhancing Rural Livelihoods

Rural livelihoods in the Tons River basin primarily depend on traditional agriculture, which currently does not produce enough output to meet the food needs of the population. Although recent efforts have focused on cultivating fruits and vegetables, these have not yet significantly addressed the needs of the growing population. This paper proposes that enhancing livelihoods can be achieved through the conservation of agro-biodiversity and the adoption of sustainable agriculture practices. Specifically, cultivating principal crops such as tomatoes, apples, potatoes, and Rajma, along with various subsidiary crops suited to the local agro-climate and altitudes, can improve productivity and food security. Additionally, integrating livestock farming and promoting homestay tourism along major trekking routes and in areas of cultural and natural significance could further enhance livelihoods in the Tons River basin. Since this region is rich in floral diversity and their economic value is very high, thus, the sustainable use of timber and non-timber products will enhance rural livelihood. The key livelihood options are summarized and discussed in this paper.

4.2 Conservation of Agro-biodiversity

Agro-biodiversity in the Tons River basin is notably rich, as detailed in Table 2. We have identified 47 crop races and cultivars, which include 7 races of food grains, 16 races of vegetables, 6 races of fruits, 3 races of oilseeds, 4 races of spices, and 10 races of pulses. There may be additional crops not listed here. Under mixed cropping system, 12 or more than 12 crops are grown together in a single crop field. This system is called 'Barahnaja system'. These crops offer significant economic and nutritional value, many of which are traditional varieties. It is essential to conserve these traditional crops while also cultivating cash crops. Both types of crops are crucial in the Tons River basin, given its diverse agro-climate, which supports the cultivation of these crops with high production and productivity.

Table 2: Agro-biodiversity in the Tons River basin

Crops*	Local name	English name	Scientific name
Food grains (7)	Dhan	Paddy	Oryza sativa
	Gainhun	Wheat	Triticum aestivum
	Jau	Barley	Hordeum vulgare
	Manduwa	Finger millet	Eleusine coracana
	Jhangora	Barnyard millet	Echinochloa frumentacea
	Koni	Millet	Setaria italica
	Mungari	Maize	Zea mays
Vegetables (16)	Palak	Spinach	Spinacia oleracea
	Shimla Mirch	Capsicum	Capsicum annuum
	Pyaj	Onion	Allium cepa
	Aalu	Potato	Solanum tuberosum
	Band Gobhi	Cabbage	Brassica oleracea
	Arbi/Pinalu	Taro root	Colocasia Esculenta
	Kaddu	Pumpkin	Cucurbita pepo
	Lonki	Bottle guard	Lagenaria siceraria
	Baingan	Egg plant	Solanum melongena
	Chhimula	Beans	Phaseolus vulgaris
	Kakadi	Cucumber	Cucumis sativus
	Bhindi	Lady finger	Abelmoschus esculentus
	Muli	Radish	Raphanus sativus
	Gajar	Carrot	Daucus carota
	Fafara	Turraea	Turraea sericea
	Chaulai	Amaranth	Amaranthus
Fruits (6)	Akharot	Walnut	Juglans regia
	Chulu/Chiraulu	Apricot	Prunus armeniaca
	Plum	Plum	Prunus domestica
	Seb	Apple	Malus domestica
	Aadu	Pear	Pyrus
	Aam	Mango	Mangifera indica
Oilseeds (3)	Til	Sesame	Sesamum radiatum
	Bhangjeera	Perilla	Perilla frutescens
Spices (4)	Sarson	Mustard	Brassica juncea
	Adrak	Ginger	Zingiber officinale
	Lahsun	Garlic	Allium sativum
	Mirch	Chili	Capsicum annum
Pulses (11)	Dhaniyan	Coriander	Coriandrum sativum
	Rajma	Kinder bean	Phaseolus vulgaris
	Urd	Black gram	Vigna mungo
	Matar	Peach	Pisum sativum
	Chana	Gram	Cicer arietinum
	Gahat	Horse gram legume	Macrotyloma uniflorum
	Moong	Green gram	Vigna radiata
	Sunta	Lentin	Phseolus lunatus
	Soya bean	Soya bean	Glycine max
	Bhatt	Black soya bean	Glycine max
	Naurangi	Nine coloured dal	Vigna mungo
	Masur	Lentin	Lens culinaris

*Total 47 crops are listed here. Source: By authors

4.3 Sustainable agricultural practices

Sustainable agriculture is crucial for poverty reduction, especially in regions like the Himalaya, where communities face challenges related to food security, environmental degradation, and economic vulnerability. By promoting practices that boost productivity, conserve natural resources, and improve livelihoods, sustainable agriculture can play a significant role in alleviating poverty in the Himalayan region (Das and Meher, 2019; Kimaro, 2019). Agroecology focuses on integrating ecological processes into agricultural systems, thereby enhancing biodiversity, soil health, and resilience to climate change (Tenzing et al., 2016). Practices such as agroforestry, terrace farming, and organic farming not only increase yields but also reduce reliance on external inputs, thereby improving the economic viability of farming and contributing to poverty reduction (Dhanta and Negi, 2018; FAO, 2019). Indigenous farming techniques, traditional crop varieties, and local agroecological knowledge are valuable

assets that bolster the resilience of Himalayan agriculture (Gioli et al., 2019; IMI-FAO, 2019; Roy and Kumar, 2018). Enhancing local value chains, improving market access for smallholder farmers, and supporting sustainable agribusinesses can further boost income generation and create employment opportunities in rural areas (Mahapatra, 2018; Mukherjee, 2018; Rasul, 2016; Shrestha et al., 2012).

In the Himalaya, traditional farming systems involve the cultivation of food grains, millets, pulses, oilseeds, fruits, and vegetables primarily for subsistence. Farming methods, including ploughing, sowing, and harvesting, are largely traditional. In many Himalayan areas, the output from these traditional crops is insufficient, leading to issues of food insecurity and malnutrition. Our objective is to recommend sustainable agricultural practices that integrate the cultivation of both traditional and cash crops, tailored to the prevailing agro-climatic conditions.

4.4 Agro-climatic zones and the principal crops

The case study villages show rich agrobiodiversity across different agro-climatic zones, as shown in Table 3. In the subtropical zone (<1000 m), villages like Nainbag, Naugaon, Lakhamandal, and Sweel grow mangoes, paddy, wheat, and onions. The sub-temperate zone (1000-1600 m), including villages such as Bigasi, Saani, Hudoli, Chandeli, and Danda Kyari, produces tomatoes, paddy, pulses, and onions. In the temperate zone

(1600-2200 m), villages like Gaichwan, Dewera, Haltadi, Kot, Sankari, Sidri, and Taluka mainly grow apples, pears, peaches, and potatoes. The cold zone (>2200 m) features villages such as Dati Mer, Dharkot, Gangad, and Osla, where Rajma, potatoes, wheat, Manduwa, and Fafara are cultivated. Wheat is grown in almost all agro-climatic zones whereas, its growing seasons vary from the summer to late summer. These villages are along major roads and trekking routes, which is why they are highlighted, though there are many more villages in the Tons River Basin.

Table 3: Agro-climatic zones and the principal crops in the study villages			
Agro-climate	Altitude (m)	Villages	Major crops
Subtropical	<1000	Nainbag, Naugaon, Lakhamandal, and Sweel	Mango, litchi, paddy, wheat, and onion
Sub-temperate	1000-1600	Bigasi Saani, Hudoli, Chandeli, and Danda Kyari	Tomato, paddy, wheat, pulses, onion, ginger, and garlic
Temperate	1600-2200	Gaichwan, Dewera, Haltadi, Kot, Sankari, Sidri, and Taluka	Apple, pear, peach, plum, walnut, apricot, potato, and wheat
Cold	>2200	Dati Mer, Dharkot, Gangad, and Osla	Rajma, potato, wheat, Manduwa, and and fafara

Source: Household-level survey

4.5 Village-wise area, production, and productivity of the principal crops

We surveyed 50 households across five villages, with 10 households from each (Table 4). Our household-level survey provided data on crop area, production, and productivity for each village. In Sweel Village, located in the Kamal River valley, tomatoes, peaches, wheat, and rice are the main crops. Peaches and wheat have the highest production and productivity, and these crops are sold locally and regionally, while paddy and wheat are primarily grown for subsistence. In Gaichwan Village, apples and pears dominate with the highest area, production, and productivity, whereas potatoes, pulses, and red rice are grown for subsistence with lower figures.

In Sankari Village, apples and pears have the highest area, production, and productivity, while potatoes, pulses, and red rice have lower figures. Dharkot Village, due to its altitude, focuses on Rajma (pulses) and potatoes (vegetables) as the principal crops, with Chaulai, wheat, and Manduwa being traditional crops. The area, production, and productivity of potatoes, Rajma, and Chaulai are similar, whereas other crops have minimal area and production. Osla Village, situated at 2700 meters, the first village along the Tons River, grows Rajma, potatoes, Chaulai, wheat, Manduwa, and Fafara. Wheat is a post-summer crop, harvested in early July. Data indicates that villages in valleys and mid-altitudes have higher productivity compared to those in higher altitudes.

Table 4: Area, production, and productivity of the principal crops			
Sweel (n=10 HHs)			
Crop	Area (ha)	Production (q)	Productivity (q/ha)
Paddy	4	100	25
Wheat	4	80	20
Tomato	2	600	300
Peach	1.6	1280	800
Gaichwan (n=10 HHs)			
Apple	10 (17000 trees)	1400	1390
Pear	2 (500 trees	100	98
Potato	2	20	18
Pulses	2	5	3
Red rice	2	50	48
Sankari (n=10 HHs)			
Apple	8 (14000 trees)	1000	125
Pear	2 (500 trees	100	50
Potato	3	30	10
Pulses	1.5	3.5	2.3
Red rice	1.5	45	30
Dharkot (n=10 HHs)			
Rajma	3	52	17.3
Potato	3.2	46	14.4
Chaulai	2.1	37	17.6
Wheat (June-July)	1.8	18	10
Manduwa	0.9	11	12.2
Fafara	1.2	18	15
Osla (n=10 HHs)			
Rajma	4	60	15
Potato	3.8	50	13.2
Chaulai	1.7	30	17.6
Wheat (June-July)	2	20	10
Manduwa	0.8	10	12.5
Fafara	1.8	13	7.2

Source: Household-level survey

Figure 3 shows the distribution of fruits, vegetables, and pulses across different altitudes. Tomatoes are the principal crop in the valley regions, particularly along the Kamal Valley, with market availability at local and regional levels in Dehradun, Vikas Nagar, and Rishikesh. Apples are grown

at middle to high altitudes, between 1200 m and 2000 m, with average market facilities. In the highland areas, Fafara, potatoes, and Rajma are the main crops.



Figure 3: (a) Tomato are ready to shell in Sweel village, (b) apple orchard in Gaichwan village, (c) Fafara is grown largely in Dharkot village, (d) Mixed crop mainly potato, Rajma, and Manduwa; Photo: By Vishwambhar Prasad Sati

4.6 Crop-wise productivity

Crop-wise productivity was analyzed to determine their values and future prospects (Table 5). Despite its small cultivation area, peach has the highest productivity in the Tons River valley, indicating that expanding its cultivation could be promising. Apple, which is economically valuable, also shows very high productivity and benefits from good transportation facilities and suitable markets in Uttar Pradesh. Pear and tomato are other promising crops with high productivity. Red rice, popular and substantially productive, is mainly grown in irrigated river valleys, particularly in the Kamal River valley and Rama Sarain area. Potatoes and Rajma in the highlands have substantial productivity, well-suited to the climate and landscape. Additionally, four traditional crops—Manduwa, Fafara, wheat, and Chaulai—are vital for livelihoods as staple foods in the Tons River valley.

Table 5: Crop-wise productivity		
Principal crops	Productivity (q/ha)	Ranking
Manduwa (N=20 HHs)	12.5	10
Fafara (N=10 HHs)	11.1	11
Wheat (N=20 HHs)	13.3	9
Chaulai (N=20 HHs)	17.6	6
Rajma (n=10 HHs)	16.15	7
Potato (n=20 HHs)	13.9	8
Rice (N=20 HHs)	34.3	5
Pear (N=30 HHs)	74	4
Pulses (N=30 HHs)	2.65	12
Tomato (n=10 HHs)	300	3
Peach (N=30 HHs)	800	1
Apple (n=40 HHs)	757	2

Source: Household-level survey

4.7 Economic valuation of principal crops

Based on the production and current market rates (in USD) of principal crops, we calculated their economic values. The majority of households are engaged in cultivating apples, followed by peaches, pulses, and pears. Fewer than 20 households out of the 50 surveyed are involved in growing other crops (Table 6). Apples generate the highest economic value (per season) at \$3,201,220, followed by peaches at \$1,248,780, tomatoes at \$365,854, pulses at \$500,000, and pears at \$457,317. These crops hold significant potential for sustaining livelihoods, suggesting that more arable land should be dedicated to their cultivation. Red rice also shows potential with an economic value of \$102,439. The economic valuation of potatoes and Rajma is on the rise, indicating promising future prospects. Manduwa, Fafara, wheat, and Chaulai, while traditionally grown and vital as staple foods, have lower economic valuations. In terms of income per household, apples yield the highest at \$80,031, followed by peaches at \$41,625, tomatoes at \$36,588, and pears at \$15,244. Income per household from rice and potatoes is substantial, while traditional crops generate lower income per household.

Table 6: Principal crops and their economic valuation (n= 50 HHs)					
Principal crops	Production (q)	Rate (USD*/1)	Total income (USD)	Income USD/HH	Ranking
Manduwa (N=20 HHs)	21	121.95	2561	128	12
Fafara (N=10 HHs)	31	73.17	2268	227	11
Wheat (N=20 HHs)	118	60.97	7195	360	10
Chaulai (N=20 HHs)	67	121.95	8171	409	9
Rajma (n=10 HHs)	112	121.95	13659	1366	8
Potato (n=20 HHs)	796	36.59	29122	1456	7
Rice (N=20 HHs)	1050	97.56	102439	5122	6
Pear (N=30 HHs)	3750	121.95	457317	15244	5
Pulses (N=30 HHs)	5125	97.56	500000	16667	4
Tomato (n=10 HHs)	6000	60.98	365854	36588	3
Peach (N=30 HHs)	12800	97.56	1248780	41625	2
Apple (n=40 HHs)	17500	182.93	3201220	80031	1

*1 USD = 82 INR (July 2024): By authors

In these villages, input to farmland beyond human labour is minimal. The state forest department provides fruit trees at a subsidized rate, and the horticultural department offers technical assistance to farmers. Livestock contributes organic manure, ensuring that all crop products are organic. Family members working on the farms provide labour around the clock. Fruit plants require substantial input for the first 5-6 years until they start fruiting, after which they need less human labour.

4.8 Altitude-wise Agro-diversity and crop productivity

In the Tons River basin, agro-biodiversity and crop productivity vary

significantly across different altitudes. The temperate zones exhibit the highest crop productivity at 377 q/ha, growing temperate fruits like apples, pears, peaches, plums, and walnuts, as well as potatoes and apricots. Both the sub-tropical and sub-temperate zones show high productivity at 102 q/ha each. In contrast, the cold zone, where traditional subsistence crops are cultivated, has the lowest productivity. Despite their lower yields, these crops have high nutritional and medicinal value. The stony and rugged terrain of the highlands contributes to the nominal production and productivity of crops in this region (Figure 4).

Altitude-wise Agro-diversity and Productivity of Crops (Tons River Basin)			
Agro-climate and altitude	Principal crops		Productivity
Cold >2200 m	Rajma, potato, wheat, Manduwa, Fafara		14.1 q/ha
Temperate 1600-2200 m	Apple, pear, peach, plum, potato, walnut, apricot		377 q/ha
Sub-temperate 1000-1600 m	Tomato, paddy, pulses, onion, garlic, ginger		102 q/ha
Sub-tropical <1000 m	Mango, litchi, paddy, wheat, onion		102 q/ha

Figure 4: Altitude-wise agro-biodiversity and crop productivity

4.9 Market facilities

Market facilities vary significantly from the river valleys to the highlands, affecting the economic benefits farmers receive from selling their crops. Villages located in valleys and middle altitudes, such as Sweel in the Kamal Valley, benefit from easier market access due to proximity to main roads, leading to substantial net profits. Similarly, apples from Gaichwan village are successfully marketed to Kanpur city in Uttar Pradesh thanks to established market networks. In contrast, remote villages like Dharkot, Gangad, and Osla face challenges due to poor road networks, leading to high transportation costs and lower returns for farmers. Perishable crops like potatoes require immediate market access or cold storage, which is often lacking in highland areas despite the crop's high potential. Similarly, while Rajma is a principal crop in these high altitudes, inadequate market facilities limit its economic benefits.

4.10 Livestock farming

Livestock plays a crucial role in the economy of the Tons River basin, serving as a supplementary source of income and support for farming. Each surveyed household owns at least two livestock, with cows predominant in the lower and middle altitudes, while goats, sheep, lambs, and horses are more common in higher altitudes. Some households also have oxen for ploughing and manure production. Generally, cows are stall-fed in the house. Every house, a place is given to cows, which in the ground floor and is called 'Ubra'. Goats are reared in the grasslands – in alpine pastureland during the winter and sub-tropical grassland during the

summer. Livestock provides essential resources such as milk, meat, wool, and manure, contributing to organic farming. Those involved in homestay tourism use milk for preparing tea and coffee for guests. Additionally, goat herding offers substantial income, and highland farmers move their livestock to summer grazing grounds like Hari Ki Dun and Kedar Kantha for about four months. The goat herders are also involved in weaving traditional clothes by goat's wool. Since this region is cold and during the winter season, it remains covered by snow, these woollen clothes are very popular, as they protect the people from severe cold waves. Abundant fodder is available in the temperate and sub-tropical grasslands and leaves of fodder trees, such as oak, are ample, livestock farming can boost the rural livelihood. Overall, livestock is pivotal for livelihood enhancement in the Tons region, benefiting from the region's favourable grazing climate.

4.11 Tourism and homestay as a livelihood option

In the Tons River Basin, tourism and homestay offer significant livelihood opportunities alongside agriculture and horticulture. The region is rich in cultural, natural, and adventure tourism. Cultural tourism thrives around key sites like Lakhamandal and Hanol, known for their ancient Shiva temples and connections to the epic tales of the Pandavas and Kauravas. Highland communities revere the Kauravas, while river valley residents honour the Pandavas, with notable sites such as the temple of Karna in Dewera attracting pilgrims. The area also hosts numerous fairs and festivals, drawing visitors year-round. Natural tourism flourishes due to the region's scenic beauty and pleasant summer climate, making it a popular destination. Adventure tourism is highlighted by renowned trekking routes like Hari Ki Dun and Kedar Kantha, which attract trekkers, particularly in the summer.

The accommodation and transportation facilities in the Tons River Basin are inadequate, but homestay tourism holds significant potential for enhancing livelihoods, especially in remote areas. A survey of 10 households revealed that while homestay facilities in lower altitudes are relatively well-developed, with sufficient rooms and amenities, the situation in higher altitudes is less favourable. There are fewer homestays in these regions, and the available facilities and rates are not as competitive. Across the 10 surveyed households, there were 73 homestays, with a total of 114 tourist visits in 2023. The average charge was \$10.24 per person per day, generating a total income of \$1,293.90 for the year (Table 7). Due to the poor quality of homestay facilities, many tourists resort to camping with tents in available spaces during their treks.

Table 7: Homestay facilities (n=10 households), 2023

Village	Homestay (rooms)	Number of tourists (yearly)	Income (USD* / tourist/day)	Total income (USD) yearly
Sweel	2	13	14.6	189.8
Gaichwan	22	26	12.2	317.2
Sankari	34	54	12.2	658.8
Dharkot	7	10	6.1	61
Osla	8	11	6.1	67.1
Total	73	114	10.24	1293.9

*1 USD = 82 INR (July 2024). Source: Household-level survey

Figure 5 highlights two homestays located in Gangad and Gaichwan villages. These wooden, intricately carved homes are designed to withstand the region's snowy winters, offering warmth and comfort. Despite similarities in room sizes and architectural styles, the quality of amenities and charges for the homestays differ between mainstream and

remote areas. Both homestays are set amidst agricultural fields, where seasonal vegetables, food grains, and fruits are organically grown. The homestay owners provide tourists with fresh produce from their farms. Figure (a) shows Fafara, a seasonal vegetable cultivated near the homestay, while Figure (b) depicts apple trees surrounding the homestay.



Figure 5: Rural homestays (a) Gangad village (b) Gaichwan village. Photo: By Vishwambhar Prasad Sati

5. DISCUSSION

In this paper, we evaluated strategies for enhancing livelihoods in the Tons River basin of the Garhwal Himalaya through agro-biodiversity conservation, sustainable agriculture, livestock farming, and homestay tourism (Figure 6). Given the region's rich agro-climate and favourable conditions, these approaches have significant potential for sustainable livelihood improvement. Currently, local agriculture consists primarily of subsistence farming with traditional crops such as millets, pulses, food grains, fruits, and vegetables. Despite their importance, the output from these agricultural practices is often insufficient. To achieve more sustainable livelihoods, it is essential to modernize these crops and shift towards more commercial practices, thereby increasing farmers' economic stability.

The research findings reveal that the Tons River basin has rich agro-biodiversity, with 47 crop races and cultivars currently grown in the region. Many of these crops are rainfed, although some, like red rice, are irrigated and thrive in the river valleys where water is plentiful. Red rice is particularly popular for its taste and nutritional value and is served to tourists by those running homestay operations. Tomatoes, which are primarily cultivated in the lower altitude valley regions, require intensive farming practices. Peach production and productivity are notably high in the valleys and middle altitudes, indicating that sustainable peach farming could significantly enhance livelihoods. Fruit cultivation in the middle and higher altitudes (1200 m to 2000 m) holds considerable promise, with apple, pear, peach, plum, apricot, and walnut being particularly beneficial.

Among the crops, apples stand out for their high income value, with both production and productivity being the highest in the region. Walnut cultivation is also prominent in the Tons River basin, although many walnuts are difficult to crack, indicating a need for more sophisticated varieties. The lack of market facilities and the perishable nature of many fruits lead to significant waste. Despite this, traditionally grown crops like potato, Rajma, and Fafara play a crucial role in sustaining livelihoods due to their high nutritional value, making their conservation important. Additionally, the production of millets has been increasing, partly due to a Government of India initiative promoting millet consumption. Farmers involved in homestay tourism offer traditional dishes such as Manduwa Ki Roti and Fafara Ka Saag to tourists, showcasing the region's rich culinary heritage.

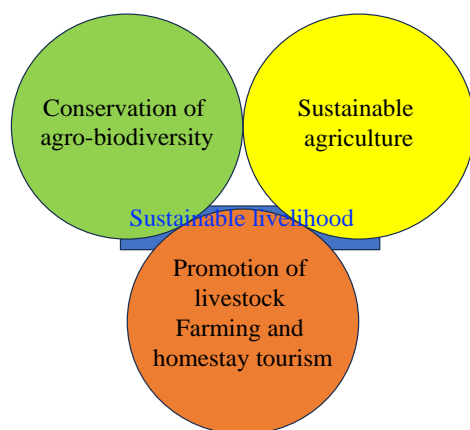


Figure 6: Sustainable livelihood approach for the Tons River basin

Cultivation of apples has emerged as a key economic activity in the Tons River basin, earning it the status of an "economic tree." Inspired by the success of apple production in Himachal Pradesh, neighbouring farmers have adopted similar practices, supported by state subsidies. This has led to a substantial increase in apple cultivation, with notable growth in area, production, and productivity. Alongside apples, the cultivation of pear, peach, plum, walnut, and apricot is also gaining momentum, with these fruits showing significant market value.

Adequate market facilities are crucial for farmers to realize the full benefits of their crop products, yet the remote location of the Tons River basin poses significant challenges. Market facilities are relatively better in the river valleys compared to the highlands, where access is particularly difficult. For instance, Osla village is accessible only via a five-kilometre trek, and Dharkot, despite being on the road, suffers from poor road conditions year-round. The lack of cold storage facilities exacerbates the issue, as perishable vegetables and fruits often spoil if not sold quickly, leading to losses for farmers. Many prefer traditional crops like millets to avoid the risks associated with perishable cash crops. High transportation

costs further erode profits, compelling farmers to sell their produce at a loss. Improving market networks, constructing cold storage facilities tailored to production levels, and enhancing transportation infrastructure could significantly improve livelihood options in the region.

Livestock farming, an allied activity to agriculture, represents a promising livelihood option in the Tons River basin. While every household maintains one or more livestock, the development of this sector remains modest despite favourable climatic conditions and ample fodder. The region supports a rich diversity of faunal resources, including cows, oxen, goats, sheep, lambs, and horses. These animals contribute significantly by providing milk and dairy products, manure for fertilizing fields, and assistance in ploughing. Livestock is integral to agricultural activities, enhancing the overall productivity and sustainability of farming practices in the basin.

Homestay tourism holds significant potential for enhancing livelihoods in the Tons River basin, given the region's appeal for trekking—especially to Hari Ki Dun and Kedar Kantha—and its rich cultural and natural attractions. The temples of Mahasu Dev, Lakhamandal, and Karna add to the area's cultural tourism, while the natural beauty supports tourism throughout the year (Sati 2021). Homestay tourism not only boosts farmers' incomes and the regional economy but also promotes local culture and cuisine. Despite the existing practice of homestay tourism, current facilities are inadequate and often poor, suggesting that improving these accommodations could further benefit both the local community and visitors.

In other Himalayan regions and mountainous areas worldwide, livelihood enhancement through agro-biodiversity conservation, sustainable agriculture, livestock farming, and homestay tourism has gained considerable momentum. While some areas have seen significant development in these aspects, the Tons River basin remains underdeveloped in this regard. It is crucial for both the government and local communities to focus on these livelihood enhancement strategies to ensure that farmers can reap the benefits of their hard work and achieve sustainable livelihoods.

6. CONCLUSIONS

This study revealed that the livelihood of rural people in the Tons River basin largely depends on traditional agriculture, which often falls short of providing adequate food for even two meals a day. Recently, some farmers have started cultivating high-value fruits and vegetables, such as tomato, apple, potato, and Rajma. Those involved in these crops are experiencing improved income and sustainable livelihoods, while others continue to face food insecurity. The Tons River basin is rich in agro-biodiversity and has favourable climatic conditions for growing a variety of crop races and cultivars. Our research underscores the importance of conserving this agrobiodiversity to enhance food security and livelihoods in the region.

A large portion of the Tons River basin relies on rainfed agriculture, which supports many crop races under these conditions. In the highlands, high atmospheric water vapor helps protect crops from drought. Sustainable agriculture offers another pathway for enhancing livelihoods by integrating both cash and traditional crops according to the region's agro-climate. The basin can be divided into three agro-climatic zones: sub-tropical for tomato production, sub-temperate for apple production, and temperate for potato and Rajma production. Other crops can be cultivated in mixed cropping systems within these zones. These crops have high production and economic value, with substantial government subsidies available to support their growth. Additionally, promoting livestock farming and homestay tourism can further enhance sustainable livelihoods. Once established, fruit cultivation and homestay tourism require minimal ongoing input while yielding high returns. Improving market networks, transportation facilities, and cold storage infrastructure will significantly boost farmers' livelihoods. Cultivating fruits will not only contribute to generate income and support a sustainable economy but also restoring the fragile ecosystem in the region. Sustainable use of timber and non-timber forest products can enhance rural livelihood along with agriculture, livestock, and tourism activities.

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