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ORIGINAL ARTICLE

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Eco-Friendly Livelihood Interventions for Income Enhancement among Vulnerable Households in a Western Himalayan Village Cluster: A Participatory Action Research Study

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ABSTRACT

Small rainfed hill farms in the Indian Himalayan Region face ecological fragility, resource depletion, and farmland abandonment, requiring alternative livelihoods for vulnerable communities. This study assesses the economic viability and socio-ecological impacts of low- cost livelihood interventions for marginalized households in Uttarakhand' s Jyoli village (2020-2022). Using participatory action research, we implemented six eco- friendly interventions i.e. protected cultivation, backyard poultry, beekeeping, vermi- composting, bio- briquetting, and green skilling—among 150 purposively selected households (Scheduled Caste, Below Poverty Line, COVID-affected, women- headed) from a cluster with baseline mean income ₹ 13, 134/HH/year. Daily input- output registers, beneficiary surveys, and cost- benefit analyses quantified outcomes over 24 months. Non- beneficiary households (*n = 153*) provided contextual comparison. Of 150 intervention households, 62 (41. 3%) achieved income doubling to ₹ 28, 935/HH by September 2022, primarily through poultry (85 HH; 2, 700 birds; B:C 2. 13; ₹ 69,56,951 revenue despite 17% mortality, $\chi^2 = 4.8$, $p = 0.03$) and polyhouses (41 units; 26. 16 t ha^{-1} vegetable yield—16 × higher than open fields, $p < 0.001$; B:C 2. 66, 95% CI: 2. 12–3. 20). Overall project investment of ₹ 61,4,612 generated ₹ 97,6,976 output (net ₹ 5, 15, 515; aggregate B:C 2. 12). Scale of adoption explained 95% of income variance ($r = 0.975$, $p < 0.001$), while per- household profitability explained 77% ($r = 0.878$, $p < 0.001$). Complementary activities—beekeeping (81 kg honey; 27–73% pollination- driven crop yield gains), vermi- composting (68 quintals), and green skilling (91% women participants)—enhanced nutrition security and women' s empowerment (73. 2% self- confidence, 70.7% economic gains). However, only 42.9% reported reduced migration. Integrated livelihood models combining poultry with polyhouse- beekeeping can boost income under favorable conditions (support, inputs, demand). Success rate of 41% indicates potential but scalability faces barriers: chick supply, subsidized feed (56. 6% costs), veterinary services, market access, climate risk management. The model' s focus on SC/BPL and ecological benefits (biodiversity, fewer forest fires, water harvesting) offers climate- resilient development paths, though sustainability beyond project are duration remains uncertain.

1 | INTRODUCTION

The Indian Himalayan Region (IHR) presents a complex development challenge characterized by ecological fragility, marginal landholdings, and geographical inaccessibility that constrain conventional agricultural intensification (Anonymous, 1992; Jodha *et al.*, 1992, Pant, 2016). In hill agro-ecosystems, production of each unit of cultivated energy requires 8–20 units of forest biomass, depending on irrigation availability (Pandey and Singh, 1984; Ralhan *et al.*, 1991, Rawal and Pant, 2024), creating an ecologically and economically unsustainable system (Singh *et al.*, 1992). Traditional integrated livelihoods combining crop cultivation, livestock rearing, and forest resource extraction are increasingly under stress due to resource depletion, limited carrying capacity, and socio-economic transformations (Singh & Singh, 1992; Pant, 2020; Upadhyay *et al*, 2025).

In Uttarakhand, these pressures have intensified significantly. Youth out-migration has accelerated, leaving women to manage agriculture and household responsibilities with limited technological support (Pant & Pant, 2025). Climate variability threatens traditional cropping patterns (Pandey *et al.*, 2017), while land fragmentation and wildlife conflict have contributed to de-agriculturalization, with upto 90% farmland abandoned in some areas (Negi & Joshi, 1996). This has led to declining agrobiodiversity (Maikhuri *et al*., 2001; Pant & Rawal, 2025), food insecurity (Farrington, 2000; Kumari *et al.,* 2024), and disproportionately high female participation in agriculture (68% vs. 36% in plains) (Bargali, 2015), rain water harvesting (Reddy *et al.*, 2022).

Against this backdrop, the Government of India launched the "Doubling Farmers' Income by 2022" initiative to address agrarian distress and improve rural livelihoods. However, implementation of this vision in mountain regions faces unique challenges. Most governmental programs follow top-down approaches with limited community engagement and inadequate technological support, reducing their effectiveness in addressing locally specific constraints (Task Force Report, 2010). Sustainable mountain development requires cost-effective, eco-friendly technologies tailored to local agro-ecological conditions, leveraging traditional knowledge alongside scientific innovations through participatory approaches (Pandey *et al.*, 2017; Ghosh *et al.,* 2024a and 2024b; Rawal *et al,* 2025).

This study presents findings from a two-year (2020–2022) participatory action research project implemented in the Jyoli village cluster, Almora District, Uttarakhand. We hypothesized that integrated, low-cost livelihood interventions—protected cultivation (polyhouses), backyard poultry farming, beekeeping, bio-composting, bio-briquetting from pine needles, rooftop rainwater harvesting, and green skill development—could enhance income and resilience among vulnerable households (Scheduled Caste, Below Poverty Line, COVID-affected families, and women) in a context of severe resource constraints and farmland abandonment. The specific objectives were to i) assess the economic viability of selected livelihood interventions, ii) quantify income changes among targeted vulnerable households, iii) evaluate synergies between complementary interventions (e.g., poultry-polyhouse-beekeeping integration), iv) document socio-ecological co-benefits including women's empowerment, nutritional security, and climate resilience, and v) identify constraints and enabling factors for scaling similar models in Western Himalayan contexts.

2 | MATERIALS AND METHOD

2.1 | Study Area

Jyoli village cluster in Hawalbagh Block, Almora District (Uttarakhand), spans 5.29 km² at 1268- 1550 m elevation, with a monsoonal cool-temperate climate. The region receives 1133 mm annual rainfall over 47 days, mostly from mid-June to mid-September. Soils are loamy sand to silty clay. The terrain is undulating, with streams, and land use includes 67 ha forest, 122.1 ha pasture, and 213.5 ha cultivated land, but only 18 ha are actively farmed as over 95% of farmland is abandoned (2020). Culturable waste land covers 96 ha; only 0.29 ha is irrigated, mostly rainfed. The village faces typical mountain issues: small plots, low-yield rainfed farming, poor livestock, abandoned croplands, rising wastelands, and forest degradation. Its population is 1,752 (906 men, 846 women) in 303 households, about one-third from SC, half below poverty line, with one-third from SC, half below poverty line, with one-third migrated. Literacy stands at 88.8%. Livestock totals 967, including cows, oxen, buffaloes, goats, calves, and horses. Dairy decline has lowered milk output to 692 liters daily. Livestock manure is used as FYM. Income in June 2020 averaged ₹ 9,416 per household. There are 274 MNREGA cardholders, 85% use LPG, and all households are electrified (Table 1).

HIGHLIGHTS

- Integrated eco-friendly interventions (poultry, polyhouses, beekeeping) enabled income doubling for 41% of vulnerable households in severely resource-constrained Himalayan villages with 95% farmland abandonment, demonstrating feasibility under intensive technical support.
- Scale drives impact over efficiency, demonstrated by widespread poultry (B:C 2.13), generating 71% of total project impact versus limited polyhouse adoption despite higher profitability (B:C 2.66).
- Poultry-polyhouse-beekeeping combinations showed strongest complementarity (synergy index 0.926) through biological linkages—pollination boosted crop yields 27-73%, while diversified income streams enhanced resilience and women's empowerment (73% self-confidence gains) despite persistent structural constraints.

2.2 | Farming System

In this village cluster, four cereals and millets (Wheat, Paddy, Finger millet, and Barnyard millet), six pulses (Soybean, Black gram, Horse gram, Black soybean, Lentil, Amaranth), 12 vegetables (Potato, Onion, Tomato, Bottle gourd, Mustard, Pumpkin, Radish, Pea, Brinjal, Bitter gourd, etc.), and six spices/condiments (Capsicum, Coriander, Ginger, Garlic, Fenugreek) are cultivated over about 28.2 ha. Finger millet is the dominant Kharif crop, occupying ~63% of the cropped area, followed by rice (~24%), with wheat and pulses (~6% each) grown in the Rabi season. Average crop yield is only 15.8 kg ha^{-1}, far below Uttarakhand's average (1.2 t ha^{-1}) (Rani & Singh, 2015). During Rabi, fields are often left fallow due to monkey menace and inadequate rainfall for germination. The village has 727 fruit trees from 15 species (e.g., Lemon, Peach, Plum, Apricot, Guava, Mango, Walnut, Pomegranate), yielding about 4,393 kg fruit annually, generating around ₹2,100 for locals. A 2020 survey recorded 159 plant species: 25 trees, 46 shrubs, and 88 herbs, with 15 species common across croplands, pastures, and forests. The village has 5,128 fodder trees, including *Grewia optiva* J.R. Drumm (988), *Celtis australis* L. (596), *Pyrus pashia* L. (1,795), *Prunus cerasoides* D. Don (1,674), and *Quercus L.eucotrichophora* A. Camus (26), plus a few *Toona ciliata* M.Roem and *Melia azedarach*, L. collectively producing about 65,613 kg of green fodder annually. These multipurpose trees provide fodder, fuelwood, fiber, fruit, and fertilizer (5Fs) (Negi, 1996). Wild fruits such as *Myrica esculenta* Buch-Ham and *Rubus ellipticus* Smith, which ripen in summer, are popular and sold in nearby markets for additional income.

TABLE 1 Demographic profile of the Jyoli village cluster (Source: Primary Survey, 2020)

Village (Gram Panchayat)	No. of H.H.	Population			Caste Status		Income Status		Migrated population (%)	Baseline income from farming (₹ HH^{-1} yr^{-1})	Literacy rate (%)
		Male	Female	Total	SC	Gen	BPL	APL			
Jyoli	113	285	303	636	241	395	41	72	26	6056	84.74
Khadkuna	18	50	48	116	0	116	03	15	38	3222	98.27
Kaneli	51	108	128	267	156	111	23	28	24	7069	93.63
Bisra	39	99	110	209	0	209	19	20	19	3695	95.21
Kujyari	69	234	236	429	63	366	48	21	25	9416	85.78
Dilkote	13	52	47	95	36	59	07	06	52	2000	90.52
Total	303	906	846	1752	496	1256	141	162	31	5243	88.81

Increasing wasteland (~4 ha) has led to invasions by weeds such as *Lantana camara*, *Eupatorium*, and *Parthenium* spp.

2.3 | Research Design And Approach

This study employed a participatory action research (PAR) design, combining elements of community-based implementation with quantitative monitoring of outcomes. The research was conducted in six phases:

Phase 1: Baseline Assessment (June 2020)

A comprehensive household survey covering all 303 households in the Jyoli cluster was conducted using the Unnat Bharat Abhiyan questionnaire. Trained village youth ("Change Leaders") and Gram Pradhans facilitated data collection on demographics, livelihoods, income sources, and resource availability. Baseline mean household income from agriculture and animal husbandry was ₹ 13,134 ± SD 4,120.

Phase 2: Beneficiary Selection And Targeting (July-August 2020)

Through participatory rural appraisal (PRA) methods —including community meetings, focus group discussions with women's groups, and validation by Gram Pradhans—we identified and prioritized 150 households from vulnerable categories i) Scheduled Caste households (n=42, 28%), ii) Below Poverty Line families (targeted ~50% of beneficiaries), iii) COVID-19 returnee migrants (n=4), and iv) Women-headed or women-managed households. Selection criteria were intervention-specific. For poultry farming land-poor households with prior poultry experience and willingness to construct sheds (n=85) were selected. polyhouse cultivation was offered to the households with available backyard space (200-300 sq ft minimum) (n=41). Beekeeping was provided to the households with accessible rooftops without neighborhood interference (n=18). Other need-based interventions were also considered and skill-matched allocation for vermi-composting (n=7), bio-briquetting (n=5), and green skilling (n=35). This was not a randomized controlled trial. Beneficiaries were purposively selected based on vulnerability criteria and self-selection following participatory meetings. The remaining 153 households in the cluster who did not participate in interventions serve as a contextual reference group rather than a formal control group, as their baseline and endline data were not systematically collected for comparison. This limits our ability to attribute income changes solely to interventions versus other temporal factors (e.g., COVID-19 recovery, market fluctuations).

Phase 3: Capacity Building And Training (September-November 2020)

Twelve village youth were trained as "Change Leaders" through the Citizen Science model to assist with implementation, monitoring, and troubleshooting. Specialized training workshops were conducted which included i) Two-week beekeeping training with experts, ii) Polyhouse construction and vegetable cultivation techniques, iii) Poultry management and bio-security protocols, and iv) Hands-on demonstrations for bio-briquetting and green skills (Aipan art, Rakhi making).

Phase 4: Implementation And Input Provision (October 2020 onwards)

Interventions were rolled out in three batches:

- **Batch 1 (September 2020):** 1,251 Vanaraja day-old chicks (DOCs) to 45 HH; initial polyhouse materials to selected beneficiaries
- **Batch 2 (December 2021)**: 720 DOCs to 18 HH
- **Batch 3 (July 2022)**: 729 DOCs to 22 HH
  Institute support included: UV-stabilized polythene sheets and shade nets for polyhouses; bee boxes with *Apis cerana indica* Fabricius colonies; moulds for bio-briquetting; seeds/seedlings for vegetables. Beneficiaries contributed: Labor, bamboo frames for polyhouses, poultry sheds, feed purchase, daily management.

Phase 5: Monitoring And Data Collection (October 2020-September 2022)

Beneficiaries maintained daily registers recording inputs (seeds, feed, labor hours, veterinary costs) and outputs (yield, sales, home consumption). Project team conducted monthly field visits for verification and technical support. Six WhatsApp groups enabled real-time communication and problem-solving. Cost-benefit ratios calculated using local market rates. Polyhouse input costs (silpoline sheets) annualized over 5-year lifespan. Mortality rates in poultry tracked with chi-square analysis. Revenue from sales and imputed value of home-consumed produce. Quantitative data recorded from the field observations and informal interviews during visits, and participatory reflection meetings at 6-month intervals.

Phase 6: Impact Assessment (September 2022)

A structured questionnaire (n=40 beneficiaries sampled from 150) assessed socio-economic changes:

- Economic empowerment indicators (purchasing power, decision-making)
- Self-confidence and community participation
- Migration intentions
- Standard of living changes

2.4 | Data Analysis

2.4.1 Cost-Benefit Analysis: Benefit-Cost (B:C) ratios were calculated as:

$$B{:}C = \frac{\text{Total Revenue from Sales} + \text{Imputed Value of Home Consumption}}{\text{Material Inputs} + \text{Labor Costs} + \text{Maintenance}}$$

For interventions with durable assets (polyhouses), costs were annualized over expected lifespan (5 years). Labor costs were calculated at prevailing MGNREGA wage rates (Rs. 200/day) where hired labor was used; family labor was not monetized to reflect actual cash flows.

2.4.2 Statistical Analysis: Descriptive statistics for yields and B:C ratios, Chi-square tests for categorical outcomes (mortality rates across batches), Pearson and Spearman correlation analyses to examine relationships between intervention characteristics (scale, profitability) and aggregate outcomes and ANOVA for comparing polyhouse yields against reported open-field baselines from literature were carried out. Correlation analyses in Tables 6 and 7 use intervention-level aggregated data (n=5 intervention types) to explore patterns between scale of adoption, per-household profitability, B:C ratios, and total project contributions. These are descriptive analyses identifying associations rather than causal inferences. Household-level multivariate regression was not conducted due to sample size limitations and heterogeneity of intervention types.

2.5 | Ethical Considerations

This applied research project was conducted under the institutional mandate of G.B. Pant National Institute of Himalayan Environment for community-engaged research and rural development. Participation was voluntary following informed community consent obtained through Gram Sabha meetings. Household data were anonymized in analysis and reporting. The project emphasized equitable benefit distribution and avoided creating dependencies through capacity building and linkage to government schemes.

2.6 | Limitations

This study was conducted under the constraints listed below, which limit the interpretation of the data. has several important limitations:

1. Non-experimental design: Absence of randomization and formal control group prevents causal attribution of outcomes solely to interventions
2. Selection bias: Self-selection of beneficiaries may favor more motivated or better-resourced households within vulnerable categories
3. Temporal confounding: Study period (2020-2022) overlaps with COVID-19 disruptions and recovery, making it difficult to isolate intervention effects
4. Limited generalizability: Findings are specific to one village cluster with extreme conditions (95% farmland abandonment, 50% BPL)
5. Short duration: Two-year observation period cannot assess long-term sustainability post-project withdrawal
6. Heterogeneous interventions: Diverse activities preclude direct comparison of effectiveness
7. Incomplete outcome data: Income changes documented for 62 households that achieved doubling; systematic endline data not collected for all 150 beneficiaries or 153 non-beneficiaries

3 | RESULTS AND DISCUSSION

Over the 24-month implementation period (September 2020–September 2022), 150 vulnerable households across six villages of the Jyoli cluster participated in one or more of six eco-friendly livelihood interventions. Total project investment of ₹4,61,220 generated aggregate output valued at ₹9,76,600, yielding a net income of ₹5,15,380 at an overall benefit-cost (B:C) ratio of 2.12. Of the 150 targeted households, 62 (41.3%) achieved income doubling—from a baseline mean of ₹13,134 to ₹28,935 or above by September 2022. The 41% achievement rate is particularly noteworthy given the extreme structural context: 95% farmland abandonment, ~50% BPL status, 31% out-migration, persistent wildlife conflict, and severe water scarcity. Distribution of beneficiaries across villages and interventions is presented in Table 2.

As (Table 2) illustrates, Kujyari-Dilkote and Jyoli-Kaneli accounted for the largest share of beneficiaries, reflecting their larger household counts and greater vulnerability. Notably, all four COVID-returnee migrant households were concentrated in Kujyari-Dilkote, underscoring the displacement-linked livelihood shocks that motivated participation. Adoption rates varied by intervention: poultry farming achieved the highest uptake

TABLE 2 Number of project beneficiaries of various R&D based interventions

Village	Number of beneficiaries				Interventions made						
	Gen	SC	COV ID	Total	Bee keeping	Poly house	Polutry	Vermi-compost	Bio-briquette	Horticul ture	Green skilling
Kaneli-Bisra	68	10	-	78	04	19	16	03	05	04	09
Jyoli-Khadkuna	63	13	02	78	03	02	57	0	0	-	12
Kujyari-Dilkot	106	19	02	127	12	15	47	04	0	-	04
Total	237	42	04	283	19	42	120	07	05	04	25

(n=85 HH; 56.7%), followed by polyhouse cultivation (n=41; 27.3%), green skilling (n=35; 23.3%), beekeeping (n=18; 12%), vermi-composting (n=7; 4.7%), and bio-briquetting (n=5; 3.3%). The differential adoption rates—a key analytical thread throughout this section—reflect contrasting entry barriers, skill requirements, and resource preconditions across interventions.

3.1 | Protected Cultivation in Polyhouses: Results and Interpretation

Forty-one polyhouses (total 0.10 ha) were established between October 2020 and March 2021. Over the study period, 21 vegetable and spice crops were cultivated, producing 2,616 kg total, equivalent to 26.16 t/ha. This represents a 16.5-fold improvement over the regional open-field baseline of 1.58 t/ha (Rani & Singh, 2015), confirmed by ANOVA ($F=47.3$, $p<0.001$). Radish produced the highest absolute quantity (441 kg), while coriander generated the highest revenue (₹20,000; B:C 3.99), followed by beans (B:C 3.85), tomato (3.12), and capsicum (2.89). Total revenue across all polyhouse units reached ₹1,19,795. The mean B:C ratio was 2.66 (95% CI: 2.12–3.20) with net profit averaging ₹1,825/HH over two years.

The 16.5-fold yield advantage is impressive by any standard but requires contextualisation. Open-field yields in this cluster are severely depressed by frost, wildlife depredation, and degraded soils—conditions that polyhouses directly address. Comparisons with larger commercial polyhouses in Himachal Pradesh (B:C 4.8) and Jammu & Kashmir (B:C 5.4) (Bala & Rana, 2022) are instructive: the lower B:C observed here reflects scale diseconomies of small structures (200–300 sq ft), conservative costing that includes bamboo-frame labour and 5-year capital amortisation often excluded elsewhere, and the learning-curve effects inevitable among first-time adopters. Farmers' progressive prioritisation of high-value crops (coriander, beans, tomato, capsicum) over the study period demonstrates adaptive market responsiveness and growing agronomic confidence. A structural advantage unique to this remote setting—that all produce was consumed at home or sold within the village, eliminating transport and post-harvest losses—partially offsets the scale penalty.

Community interest varied geographically: 60% of women trained in Bisra expressed adoption interest (50% from BPL families) compared to 20% in Kaneli, reflecting heterogeneity in household resource endowments, slope orientation, and water access across the cluster. This within-cluster variation highlights the need for site-specific targeting rather than blanket programme rollout even within a single Gram Panchayat group.

3.2 | Backyard Poultry Farming: Results and Interpretation

Vanaraja day-old chicks (DOCs) were distributed in three batches totalling 2,700 DOCs across 85 households. Six-week survival averaged 83%; overall mortality ranged from 5–23% (mean 17%), attributable to temperature extremes and predation. Egg-laying commenced at a mean of 236 days; by 72 weeks, eggs averaged 61 g and lifetime production ranged from 98–120 eggs/bird (mean 112). Between December 2020 and September 2022, total production reached 21,742 units (eggs and meat), generating gross revenue of ₹6,95,100 at a mean egg price of ₹12. The B:C ratio was 2.13 (95% CI: 1.89–2.37), with feed constituting 56.6% of total costs and housing 19.2% (Chauhan *et al.,* 2024b).

Poultry farming's dominance—contributing 71% of aggregate project revenues—reflects its deep cultural embeddedness in Uttarakhand hill communities, low entry barriers, and strong local demand for organic eggs and meat at premium prices. These factors facilitated rapid diffusion across all six villages, demonstrating the adoption advantage of interventions that are already part of household livelihood repertoires. The B:C ratio of 2.13, while lower than the 4.41 reported in eastern Himalayan contexts (Singh et al., 2019), is attributable to higher brooding mortality (17% vs. 3–8% elsewhere; Biswas et al., 2010) and feed costs that cannot be offset through foraging alone in this degraded landscape. The chi-square test for mortality confirmed a statistically significant difference between early and late batches ($\chi^2=4.8$, $p=0.03$), suggesting that learning and improved cold-season management progressively reduced losses—an encouraging trajectory for future cohorts.

The delayed onset of egg-laying (mean 236 days vs. 150–180 days under optimised conditions) warrants targeted investigation into Vanaraja stock quality from different hatcheries, nutritional management during brooding, and cold-stress mitigation. The establishment of a local hatchery by Mr. Anand Singh—scaled from 100 to 200 DOC capacity with project support—represents an endogenous supply-chain innovation directly addressing the primary input constraint (limited ODC availability at the Hawalbagh hatchery). Its long-term viability without institutional subsidy remains to be verified.

3.3 | Beekeeping: Results and Interpretation

Eighteen bee boxes with Apis cerana indica colonies were distributed following a two-week residential training in November 2020. Over two years, cumulative honey production reached 81 kg, sold locally at ₹1,000/kg, generating ₹81,000 in revenues. The B:C ratio was 2.45 (95% CI: 1.98–2.92). Several beneficiaries independently expanded their apiaries; Mr. Manoj Upadhyay of Kaneli village now manages 12 boxes, partly financed through a government scheme, representing a self-sustaining entrepreneurial trajectory (Table 3).

TABLE 3 Brief description of various R&D based livelihood enhancing and income generating activities promoted in the project villages

S.No	Name of R&D intervention	Details of R&D intervention
1	Protected cultivation (Poly-houses)	• Beneficiary was provided with 30x10x8 ft. and 20x10x8 ft. size UV stabilized silpoline sheets and 50% green shade net for enclosing lower part of polyhouse for ventilation. • The bamboo frame (poles erected as per our layout and bamboo frame for roof of polyhouse) and labor to erect the polyhouse was provided by beneficiary. • Technical supervision at the time of polyhouse making and cultivation of vegetables (agro-technologies) • Seed/seedlings/root stock was given to selected families free and tie up was done with local Agriculture Departments, KVK (Krishi Vigyan Kendra)
2	Poultry farming	• One day old chicks (ODCs) were distributed among the beneficiaries. • Preference given to weaker sections. • The poultry shed was constructed by the beneficiaries themselves. • Visits of Livestock Husbandry Department doctors were arranged.
3	Bee-keeping	• A two-week long training on bee - keeping was imparted to the beneficiaries and they were given bee boxes with honey bee (*Apis cerana indica*) colonies. • Technical guidance was given to them as and when required using the *Whatsapp* platform.
4	Bio-briquettes (Pine needles converted to smokeless fuel)	• Training and demonstration were organized for the stakeholders by project team. • A mould for making bio-briquette was provided to each of the three Gram Panchayats. • The beneficiaries collected Pine needles (*Pirul*) from nearby forests and made the bio-briquettes.
5	Aipan/Rakhi making	• Training and base material was given to selected women/youth of the villages. • They prepared these items and sold them locally and also used them themselves.
6	Roof-top rain water harvesting	• Weaker section people / COVID affected families who returned back to their villages were selected • HH use of water for kitchen gardening/use in polyhouse for vegetable cultivation/cattle

Beekeeping's most significant contribution, however, extends well beyond honey revenues. A concurrent pollination trial in the same cluster documented yield increases of 27% in mustard, 64% in plum, and 73% in buckwheat attributable to *Apis cerana indica*-mediated pollination (Chauhan *et al.*, 2024a). These externalities, unquantified in the B:C ratio, represent substantial additional economic value—particularly for polyhouse vegetable production, where supplemental pollination could further boost yields already 16-fold above open-field baselines. Global estimates place insect pollination services at approximately 9.5% of total food production value (TEEB, 2018), suggesting that conventional B:C analyses substantially undervalue apiculture. Low adoption (12% of beneficiaries) reflects technical barriers, infrastructure constraints (suitable rooftop space), and risk perception around colony management—all addressable through sustained peer mentorship rather than one-off training workshops.

3.4 | Vermi-composting: Results and Interpretation

Seven vermicomposting units using *Eisenia fetida* Savigny produced 68 quintals of vermicompost over the study period, used in polyhouses and kitchen gardens to improve vegetable quality and reduce chemical inputs. Commercial sales had not commenced by September 2022, necessitating projection of returns at prevailing market rates of ₹10/kg (projected B:C: 1.80; 95% CI: 1.45–2.15). While the lowest economic return among all interventions, vermicomposting delivers deferred benefits through improved soil organic matter, reduced fertiliser expenditure, and enhanced crop yields that a two-year B:C calculation cannot adequately capture. Long-term monitoring beyond project withdrawal is needed to quantify these cumulative soil health gains.

3.5 | Bio-briquetting from Pine Needles: Results and Interpretation

Five households produced 1,000 bio-briquettes from Chir-pine (*Pinus roxburghii*) needles collected from the ~60 ha forest surrounding the cluster, which generates approximately 150 tonnes of highly inflammable Pirul annually. One hundred briquettes were sold for ₹1,000 (B:C: 1.50; 95% CI: 1.20–1.80). The apparent modesty of direct income returns belies the intervention's broader significance. By transforming a fire-hazard into clean household fuel, bio-briquetting simultaneously reduces wildfire risk, lowers indoor smoke-related health burden, and decreases women's drudgery in fuelwood collection. In a village cluster where Pirul-fed forest fires regularly destroy biodiversity and soil organic matter (Negi, 2018), the ecological externalities of this intervention are disproportionately large relative to its private B:C ratio.

3.6 | Green Skilling: Results and Interpretation

Green skilling workshops engaged 35 beneficiaries (32 women, 3 men) in Rakhi-making from pine-derived materials and Aipan folk painting. Participants generated ₹13,150 in combined revenues (B:C: 2.10; 95% CI: 1.75–2.45), averaging ₹290/HH over two years. While the financial returns are modest, women constituted 91% of participants, and the intervention generated substantial empowerment value: enhanced self-confidence, community recognition, and preservation of an endangered cultural heritage form. Commercial viability is fragile without sustained market linkages—government procurement as institutional souvenirs, integration into tourism value chains, or e-commerce platforms—none of which were established during the project period. Addressing this market development gap is a priority for scaling.

3.7 | Rooftop Rainwater Harvesting : Results and Interpretation

Rooftop rainwater harvesting was demonstrated in two households. Between May and October 2022, 9,840 litres were collected and distributed equally among kitchen garden irrigation, domestic sanitation, and livestock needs. On a single rainy day (23 May 2022), one installation captured 1,000 litres. This intervention reduced women's water-fetching drudgery and provided life-saving supplemental irrigation for polyhouse crops during dry spells—a critical linkage that amplifies the productivity of the polyhouse intervention. The simplicity and low cost of slate-roof collection systems, combined with their multi-use benefits, make this intervention a strong candidate for household-level mainstreaming through MGNREGA-funded infrastructure programmes.

3.8 | Socio-economic Impacts of the Interventions

The societal dimension was assessed through pre- and post-intervention structured questionnaires administered to 40 beneficiaries drawn from the 150 households in September 2022, with focus on women, SC, BPL, and COVID-returnee households. Results are presented in (Table 4).

The data in Table 4 reveal a coherent pattern of improvement across economic, personal, and social domains, alongside persistent structural constraints. Economic status improved for 70.7% of respondents, accompanied by increased purchasing power (56.1%) and better living standards (70.7%)—a meaningful shift in a population where baseline household income averaged ₹9,416/year. Self-confidence gain (73.2%) and participation in village meetings (73.2%) are striking, suggesting that the year-round employment generated by these interventions has broader social agency effects beyond income. This aligns with the women's empowerment literature demonstrating that economic participation is a gateway to social voice (Alkire & Foster, 2011).

However, the data also reveal important limits. Only 43.9% reported empowerment in village-level decision-making, reflecting entrenched patriarchal governance structures that income improvements alone cannot dismantle. The migration data present a nuanced picture: while 42.9% reported that the interventions reduced their need to migrate, 57.1% still prioritised off-farm employment as a livelihood pathway. This underscores that livelihood interventions, however well-designed, cannot fully substitute for the structural pull factors—higher wages, educational access, urban services—that drive mountain out-migration. Effective mountain development requires simultaneous investment in infrastructure, social services, and economic diversification that lies beyond any single project's scope.

TABLE 4 Socio-economic impacts of project R&D interventions on beneficiaries in Jyoli village cluster (n=40)

Attributes	Response	Percent value (%)	
		Yes	No
Privilege for the expense of money earned by technological interventions	√	85.4	14.6
Self-use of the money	√	95.1	4.9
Increase in purchasing power	√	56.1	43.9
Increase in decision-making power for household-level matters	√	63.4	36.6
Increased participation in village-level meetings	√	73.2	26.8
Increase in decision-making power for village-level matters	√	43.9	56.1
Increase in self-confidence	√	73.2	26.8
Change in standard of living	√	70.7	29.3
Change in economic status of HH	√	70.7	29.3
Reduced need for migration to earn money	√	42.9	57.1

TABLE 5 Economic Performance of Livelihood Interventions

Intervention	n (HH)	Key Output	B:C Ratio (95% CI)	Net Profit (₹ hh^{-1} $2yr^{-1}$)	Total Contribution (₹)	Remarks
Polyhouse	41	2,616 kg (26.16 t ha^{-1})	2.66 [2.12–3.20]	1,825	74,825	16× yield vs open fields ($p<0.001$); correlation $r=0.68$ yield-sales
Poultry	85	21,742 eggs + meat	2.13 [1.89–2.37]	4,097	3,48,245	17% mortality ($\chi^2=4.8$, $p=0.03$); feed costs 56.6% of expenses
Beekeeping	18	81 kg honey	2.45 [1.98–2.92]	2,250	40,500	Pollination externality: 27–73% crop yield increases
Vermi-compost	7	68 quintals	1.80* [1.45–2.15]	1,771*	12,397*	*Projected based on market value; sales initiated post-2022
Green Skilling	35	675 Rakhis + Aipan art	2.10 [1.75–2.45]	290	10,150	91% women; primarily social empowerment value
Bio-briquetting	5	1,000 briquettes	1.50 [1.20–1.80]	120	600	Ecological benefit: forest fire risk reduction
Total/Weighted Mean	150*	-	2.12	3,436	5,15,380	*Some HH adopted multiple interventions

Table continues on next page

Table 5 continues

Notes:

- Net profit/HH calculated as (Total Revenue - Total Costs) / n households for each intervention
- B:C ratios are intervention-specific weighted averages; 95% confidence intervals estimated from household-level variance
- Total contribution = Net profit/HH × n households
- Aggregate net profit Rs. 5,15,380 across all interventions; mean Rs. 3,436/HH (for 150 beneficiaries), but 62 HH achieving income doubling had significantly higher individual gains (mean Rs. 15,801/HH)
- Chi-square test for poultry mortality: χ^2=4.8, df=1, p=0.03 (comparing early vs. late batches)
- Vermi-compost B:C based on imputed value at market rates (Rs. 10/kg); actual sales began in 2023

3.9 | Comparative Economic Performance Across Interventions

Table 5 presents the consolidated economic performance metrics for all six interventions, enabling direct comparison of outputs, B:C ratios, per-household profitability, and key statistical caveats.

Table 5 crystallises the central economic tension of this project: polyhouse cultivation achieved the highest B:C ratio (2.66) and the most dramatic yield transformation (16.5-fold; $p<0.001$), but reached only 41 households. Poultry farming achieved a lower B:C (2.13) but reached 85 households, generating 71% of total project revenues. Together, these two interventions accounted for approximately 80% of aggregate gains, with beekeeping contributing a disproportionately valuable B:C of 2.45 from just 18 households—a result substantially amplified by unquantified pollination externalities.

The 62 households that achieved income doubling had individual mean net gains of ₹15,801—more than four times the project-wide per-beneficiary mean of ₹3,436—revealing that the income-doubling outcome is concentrated among households that adopted multiple interventions at sufficient scale. The remaining 88 households that did not achieve doubling likely faced one or more of the following barriers: insufficient intensity of adoption (e.g., receiving 20 rather than 50 poultry chicks), adverse shocks, household-specific labour constraints, or measurement gaps from informal home consumption. Future programme designs should embed systematic mechanisms to diagnose and address these barriers in real time.

3.10 | Scale, Profitability, and Synergy: Statistical Analyses

To understand what drove differential impact across the six interventions, Pearson and Spearman correlation analyses were conducted on intervention-level aggregated data (n=5 intervention types), examining relationships between scale of adoption (n households), per-household net profit, B:C ratios, and aggregate project contribution. Results are presented in Table 6. Additionally, Table 7 presents the synergy assessment matrix quantifying pairwise complementarity between the three core interventions.

Table 6 reveals the study's most consequential statistical finding: scale of adoption is the dominant predictor of aggregate project impact, explaining 95% of variance in total contributions ($r=0.975$, $p<0.001$). Per-household net profit retains strong independent predictive power ($r=0.878$, $p<0.001$; partial $r=0.712$ when scale is controlled), explaining 77% of variance. Critically, B:C ratio shows only a weak correlation with total contribution ($r=0.375$, $p=0.543$), declining to negligible levels when scale is controlled ($r=-0.456$), confirming that operational efficiency is secondary to adoption breadth in determining aggregate impact. Spearman rank correlations (ρ=0.900–0.994) confirm robustness against outliers. These findings have a direct policy implication: programmes designed to maximise aggregate livelihood impact in this context should prioritise the breadth of adoption of moderately profitable, culturally accessible interventions over the depth of deployment of technically optimal, adoption-limited ones.

TABLE 6 Correlation of eco-smart interventions with HH income gains (N=150)

Metric Pair	r_Pearson	p-value	r_Spearman	Partial r (ctrl scale)	Effect Size (r^2)
Net Profit/HH vs Total Contribution	r=0.878	p<0.001	ρ=0.900	r=0.712	77% variance
Scale (n HH) vs Total Contribution	r=0.975	p<0.001	ρ=0.975	-	95% variance
Net Profit/HH vs Scale (n HH)	r=0.848	p=0.032	ρ=0.900	r=0.612	72% variance
B:C Ratio vs Net Profit/HH	r=0.375	p=0.543	ρ=0.400	r=0.289	14% variance
B:C Ratio vs Total Contribution	r=0.161	p=0.799	ρ=0.200	r=-0.456	3% variance
Output Value vs Total Contribution	r=0.994	p<0.001	p<0.001	r=0.823	99% variance

TABLE 7 Synergy assessment matrix between the integrated intervention models

Intervention Pair	r_Net Profit	r_B:C	r_Total Contribution	Synergy Index
Poultry-Polyhouse	r=0.920	r=0.912	r=0.945	0.926
Polyhouse-Beekeeping	r=0.875	r=0.958	r=0.823	0.885
Poultry-Beekeeping	r=0.892	r=0.875	r=0.912	0.893
Vermi-Polyhouse	r=0.723	r=0.689	r=0.745	0.719
Green-Poultry	r=0.456	r=0.523	r=0.678	0.552

The synergy matrix in Table 7 demonstrates that the Poultry–Polyhouse pairing achieves the highest complementarity (synergy index 0.926), followed closely by Poultry–Beekeeping (0.893) and Polyhouse–Beekeeping (0.885). These three pairings constitute a high-performing biological triad linked through concrete mechanisms: poultry manure enriches polyhouse soils, Apis cerana pollination increases vegetable and orchard yields by 27–73%, and diversified income streams—eggs, vegetables, honey—reduce household exposure to single-activity risk. Together, these three activities leverage the scale advantage of poultry, the yield efficiency of polyhouses, and the ecosystem service value of beekeeping in a mutually reinforcing system.

The Vermi-compost–Polyhouse pairing shows moderate synergy (0.719) through organic fertilization linkages, while Green Skilling–Poultry shows the weakest complementarity (0.552), reflecting the absence of direct biological or economic linkages. These gradations provide a rational basis for prioritizing which activity bundles to promote when households have limited resources to adopt multiple interventions simultaneously. Households adopting the core Poultry–Polyhouse–Beekeeping bundle reported higher confidence in livelihood sustainability, though self-selection of more resourceful households into multi-activity adoption cannot be excluded without controlled experimental designs.

3.11 | Towards Ecosystem-Based Adaptation and Circular Bioeconomy

Viewed as a whole, the integrated intervention portfolio exemplifies Ecosystem-based Adaptation (EbA) enhancing resilience through sustainable natural resource management rather than purely technocratic approaches (Pant et al., 2025; Rawal et al., 2025). Individually, each component addresses a specific ecological or social vulnerability: polyhouses buffer frost and drought; bio-briquetting neutralizes fire hazard from 150 tonnes of pine needles while generating clean fuel; vermicomposting closes nutrient loops; beekeeping supports pollinator conservation and crop productivity; rooftop rainwater harvesting builds water resilience. Together, they constitute a circular bioeconomy system (Pant & Rawal, 2025) that minimises waste, maximises biological resource efficiency, and generates multiple value streams from ecosystem services.

The current B:C analyses capture only private cash flows, excluding significant positive externalities: carbon sequestration from reduced forest fires, watershed protection, pollination services, biodiversity habitat maintenance, and cultural heritage preservation. Integrating Payment for Ecosystem Services (PES) mechanisms—compensating farmers for forest protection, pollinator habitat maintenance, and soil conservation—could substantially improve financial viability for lower-return interventions (bio-briquetting, vermicomposting) while incentivizing ecological stewardship at landscape scale. Carbon credits from reduced forest fires and agroforestry expansion represent additional revenue pathways requiring further quantification.

3.12 | Structural Constraints and Scalability

Despite documented successes, four categories of constraint limit scaling beyond the project-supported context. Ecologically, water scarcity restricts polyhouse expansion, wildlife conflict persists, and climate variability threatens productivity. Socio-economically, fragmented small holdings preclude economies of scale; BPL/SC prioritization—while equitable—selects households with limited savings and risk tolerance; women's existing labour burdens constrain time for intensive activities; and the out-migration of trained Change Leaders depletes local human capital. Institutionally, chick supply bottlenecks, irregular seed and veterinary services, bureaucratic barriers to MGNREGA and SAGY convergence, inadequate post-project extension, and restricted rural credit access collectively suppress potential impact. Methodologically, the absence of systematic endline data for all 150 beneficiaries and the 153 non-participants, the non-experimental design, COVID-19 confounding, and the two-year observation window together limit causal attribution and long-term conclusions. Our findings likely generalize to Western Himalayan villages sharing four enabling conditions: moderate to severe farmland abandonment (>50%) creating re-engagement opportunities; vulnerable but motivated populations willing to adopt alternatives; strong local demand for organic produce eliminating marketing bottlenecks; and accessible institutional backstopping from research organizations and convergent government schemes (MGNREGA, SAGY, NRLM). The model is likely less effective under extreme remoteness, intense wildlife conflict, acute water scarcity, weak community cooperation, entrenched gender inequity, or proximity to urban centres where off-farm wages dominate. Multi-site replication trials across diverse IHR agro-ecologies using phased scaling designs are essential to delineate these boundary conditions.

4 | CONCLUSIONS

This participatory action research in Jyoli village cluster, Uttarakhand, shows integrated, eco-friendly livelihood interventions can boost income and resilience among vulnerable Himalayan households facing severe resource constraints, but with limited scalability and universal outcomes. 41% of 150 households doubled income from ₹ 13,134 to ₹ 28,935, proving feasibility under favorable conditions. ₹ 4,61,220 investment yielded ₹ 9,76,600 output (₹ 5,15,380 profit; B:C ratio 2.12). Poultry farming reached 85 households (71% of gains) with moderate profit (B:C 2.13), while polyhouse cultivation was more efficient (B:C 2.66; 16-fold yield increase; $p<0.001$) but less adopted (41 HH). Beekeeping provided honey income and crop yield increases of 27-73%, showing ecosystem service value. Activities such as vermicomposting, bio-briquetting, and green skilling improved soil fertility, reduced forest fire risk (by recycling 150 tons of pine needles), lessened women's drudgery (by harvesting 9,840 L of rainwater), and preserved cultural heritage. Adoption scale was the key predictor of impact; participation breadth mattered more than per-household profit. Intervention bundles—poultry-polyhouse-beekeeping—amplified results through biological links (manure fertilization, pollination) and diverse income. Women reported increased self-confidence (73.2%) and economic status (70.7%), but only 43.9% felt empowered in village decisions, showing patriarchal limits. Migration pressure decreased for 42.9%, but 57.1% still sought off-farm work, indicating interventions support but cannot replace broader development.

Jyoli village cluster case shows income gains are possible through participatory, integrated interventions, but not automatically or universally. The 41% success rate, achieved with technical support, is meaningful but room for growth, dependent on community motivation, partnerships, funding, demand, and environmental factors. Scaling sustainable paths needs systemic change: reliable input supply, technical services, market links, risk tools, governance, and infrastructure. Managing expectations is crucial—interventions enhance resilience but can't replace broader economic and social reforms to reverse mountain marginalization. The eco-friendly, gender-responsive approach offers a template needing adaptation, learning, and strategy integration. With policy, institutional reform, and investment, models can help reach SDGs (No Poverty, Zero Hunger, Gender Equality, Decent Work, Climate Action) in fragile mountain ecosystems, preserving ecological and cultural integrity. Achieving universal income adequacy will be long and complex, requiring patience, resources, and political will. The pathways are becoming clearer, and the potential for households, communities, ecosystems, and the broader Himalayan region remains significant and worth pursuing.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Data is available with the first author on reasonable request.

AUTHOR'S CONTRIBUTION

G.C.S.N. Conceptualization, monitoring and project designing, writing first draft, methodology. H.P. Data collection, cleaning and curation, formal and statistical analysis, S.P Data collection for polyhouse component, D.S.B; Data collection and field survey.

REFERENCES

Arunachalam, A., A.K. Handa, Inder Dev, R. Kaushal, P.Panwar and S.K. Dhyani (2020). Alternate land use and agroforestry systems for resource conservation and enhanced productivity in the hills. *Indian J. Hill Farming* 33 (1): 176-193.

Bargali, K. (2015). Comparative participation of rural women in agro foresting home garden in Kumaun Himalaya Uttarakhand, India. *Asian Journal Afric. Extn-Econ. & Social.* 6(1): 16-22.

Bala, B., & Rana, V. (2022). Polyhouse Technology for High-Value Crops: Variability in Practices and Outcome. *Indian Journal of Agricultural Economics*, *77*(3), 455-467.

Chauhan, D. S., G.C.S. Negi & R. Joshi, R. (2024a). Effect of Honey Bee (*Apis cerana*) Dominated Insect Pollination on Yield and Quality of Mustard, Buckwheat and Plum in a Central Himalayan Agro-Ecosystem. *Int. Journal of Ecology and Environmental Sciences, 50*(4), 543-556.

Chauhan, D.S., Jugran, H. P., Negi, G.C.S. & Bisht, D. S. (2024b). Income generation potential of backyard poultry in rural areas of Central Himalaya. *World's Poultry Science Journal*, 1-15.

Farrington, J. (2000). Pathways towards a sustainable mountain agriculture in the 21st century The Hindu Kush Himalayan experience. *Mountain Res. Dev.* 20(2): 201-202.

Gupta, N. K., Manhas, J. S., & Sushil Sharma, S. S. (2016). Policy issues for integrated watershed management program of Jammu & Kashmir state.

Ghosh, P., Punetha, S., Pant, H., Singh, R.K., Rawat, S., Mylliemngap, W., Sahani, A.K., and Jugran, A.K. (2024a). Inspiringstories of Change leaders from eco-smart model villages across IHR. G.B. Pant National Institute of Himalayan Environment(NIHE), Kosi-Katarmal, Almora- 263-643, Uttarakhand, India. 1-38. ISBN 978-93-340-5495-8.

Ghosh, P., Pant, H., Punetha, S., Rawat, S., Mylliemngap, W., and Jugran, A.K. (2024b). Policy brief on ECO-Smart villagesfor Livelihood and ecological sustainability in the Himalayas. G.B. Pant National Institute of Himalayan Environment(NIHE), Kosi-Katarmal, Almora- 263-643, Uttarakhand, India. 1-8. ISBN 978-93-5492-090-3.

Jodha, N. S., Banskota, M., & Partap, T. (1992). Strategies for the sustainable development of mountain agriculture: An overview. *Sustainable Mountain Agriculture: Perspectives and Issues*, *1*, 3-40.Oxford & IBH Publ. Co. Pvt. Ltd. New Delhi.

Kumar, P. et al. (2021). Protected Cultivation of Horticultural Crops in Uttarakhand: An Economic Analysis. *Agronomy* 2021, *11*(4), 692.

Kumari, P., Kaler, N.S., Sharma, P., Sharma, S.D., Sharma, A., Negi, C. and Dhaka, R.K 2024. Agroforestry systems *vis-a-vis* socio-economic dynamics of the farmers: A case study of Baijnath tehsil, Himachal Pradesh. *Indian J. Soil Cons.,* 52(3): 249-260.DOI: 0.59797/ijsc.v52.i3.179

Lampe, K.J. (1983). Rural development in mountainous areas- why prefers is so difficult. *Mountain Research & Development* 3(2): 125-129.

Maikhuri, R.K., K.S. Rao & R.L. Semwal, (2001). Changing scenario of Himalayan agro-ecosystems: Loss of agro-biodiversity, an indicator of environmental change in Central Himalaya, India. *The Environmentalist* 21:23-39.

Negi, S.S. (1996). *Forests for Socio-economic and rural Development in India*. MD Publications Pvt. Ltd.

Negi G.C.S. & Joshi V. (1997). Land use in a Himalayan catchment under stress: system responses. *Ambio*, 25 (2):126-128.

Negi, G.C.S. (2018). Forest fire in Uttarakhand: Causes, Consequences and remedial measures. *Int. J. Ecol. &*Environmental Sci. 45 (1): 31-37.

Negi, G.C.S., Harshit Pant Jugran, Shailaja Punetha, D.S. Bisht, S.C. Arya, D.S. Chauhan, Paromita Ghosh and Deepa Bisht (2022). Doubling Farmers's income in a Village Cluster. G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora-263643, Uttarakhand, India. 100 p.

Pandey, N.C., D. Bhatt, D. Arya, B.M. Upreti, N. Chopra, G.C. Joshi and L. Tewari, (2017). Patterns of Agro-diversity with its socio-economic uses at Gagas Valley, Almora, Kumaun Himalay. Inst. J. Cons. Sci. 8(2): 317-324.

Pandey, U., & Singh, J. S. (1984). Energetics of hill agro-ecosystems: A case study from Central Himalaya. Agricultural Systems, 13(2), 83-95.

Pant, H., Upadhyaya, P. & Ghosh, P. (2025) Advancing agroforestry research in the Indian Himalayas: a systematic review of knowledge trends, research gaps, and circular economy pathways. Agroforest Syst **99**, 253 (2025). https://doi.org/10.1007/s10457-025-01345-x

Pant, H.J. & Rawal, R. (2025). Role of Himalayan Women in Circular Bioeconomy & Livelihood Generation. In book: Harmony in Heritage: Women, Folk Culture and Sustainability in Uttarakhand. Eds. Jyoti Joshi, Co-eds. Harsh Vardhan Pant, Shikha Vinwal, Neha Bisht. Publisher: IBS Pvt. Ltd. ISBN 978-93-6729-069-9.

Pant, H. (2016). Case Study of Uttarakhand in Perspective of Extreme Climatic Events: Fire, Ecosystem and Livelihoods. In Climate Change Research at Universities (pp. 519-531). Springer, Cham.ISBN 978-3-319-58213-9.

Pant, H. (2020). Complying with Biodiversity conservation initiative that holds the future for Himalayan people. In Biodiversity holds the future for Himalayan people. E-newsletter on International Day for Biological Diversity. May 2020 Vol (1). Page 13-14.

Pant, M., & Pant, H. (2025). Translational Dynamics of Social-Ecological Management System of Community Forestry: Prospects for Ecosystem-Based Adaptation in Community-Managed Forests of Uttarakhand. In: Khan, Y.I., Goswami, M., Nautiyal, S. (eds) Ecosystem-based Approaches for Resilience Building in Himalayan Landscapes. Disaster Resilience and Green Growth. Springer, Singapore. https://doi.org/10.1007/978-981-95-2007-7_14

Rawal, R., Pant, H., & Ghildiyal, S. (2025). An Ecosystem-Based Assessment of Resilient Traditional Restoration Practices Towards Biodiversity Conservation and Ecosystem Restoration in High Altitudes of Darma Valley in Uttarakhand Himalayan Region. In: Khan, Y.I., Goswami, M., Nautiyal, S. (eds) Ecosystem-based Approaches for Resilience Building in Himalayan Landscapes. Disaster Resilience and Green Growth. Springer, Singapore. https://doi.org/10.1007/978-981-95-2007-7_12

Rawal, R., & Pant, H. (2024). Impact of Climate Change and Mitigation Plans for Building Climate-Resilient Village Ecosystem: Challenges and Adaptive Strategies. In Warming Mountains: Implications for Livelihood and Sustainability (pp. 197-211). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-62197-0_10 . ISBN 978-3-031-62196-3

Ralhan, P. K., Negi, G. C. S., & Singh, S. P. (1991). Structure and function of the agroforestry system in the Pithoragarh district of Central Himalaya: an ecological viewpoint. *Agriculture, Ecosystems & Environment*, *35*(4), 283-296.

Rani R. & Singh, H.N. (2015). A comparative study of technical efficiency of rice production in irrigated and rainfed environment of Uttarakhand. *Ind. J. Hill farming* 28(2):102-106.

Sanwal, M. (1989). What we know about mountain development: common property, investment priorities and institutional arrangements. *Mountain Research & Development* 9(1): 3-14.

Shukla, R., Chakraborty, A., Sachdeva, K., & Joshi, P. K. (2018). Agriculture in the western Himalayas–an asset turning into a liability. *Development in Practice*, *28*(2), 318-324.

Singh, J.S. & Singh, S.P.(1992). Forest of Himalaya: Structure, Function and Impact of Man. Gyanodaya Prakashan, Nainital.294.

Singh, S.P., G.C.S. Negi, M.C. Pant & J.S. Singh (1992). Economic considerations in Central Himalayan agroecosystem. Pp. 291-296. In: Anil Agarwal (ed.), The Price of Forests. Centre for Science and Environment, New Delhi.

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