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Market performance and supply chain selection dynamics for vegetables grown through sustainable practices in the Northwest Himalayan region

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The production of marketable vegetable crops in the Northwest Himalayan region is crucial for bolstering the economy and sustaining the livelihoods of farming communities in the area. The factors influencing vegetable crop production, marketing, and farmer livelihoods include the selection of output market supply chains. Recognizing the importance of these aspects, this study examines the key determinants influencing farmers' decisions regarding marketing supply chain selection. The study has highlighted the socio-economic dimensions of the area and its dwellers, further attempted to understand the cost of natural farming cultivation, followed by understanding the resource utilization in the natural farming practices, analytical representation of marketing components associated with the natural farming cultivation, and also attempted to analyze the key production and marketing problems associated with the natural farming. The concerned study has presented the analytical aspects of marketing supply chains comprehensively. The findings revealed that three primary marketing supply chains were prevalent in the study area. Among these, SC - C (Producer-Local Trader-Wholesaler-Retailer-Consumer) was the most commonly used, with 63% of the produce marketed through this supply chain, reflecting a preference for intermediary-based systems due to limited direct market access. The study reported facing significant marketing challenges, including a lack of access to specialized markets, an absence of fair pricing, and inadequate government support. Moreover, issues such as wholesalers not consulting farmers while selling their produce, lack of training and extension services, and poor market infrastructure were highlighted as key constraints. These marketing problems hinder farmers from obtaining fair value for their natural farming produce. The study emphasizes the need for improved market access, enhanced training facilities, and policy interventions to address these challenges and improve the overall marketing efficiency of natural farming systems in the region.

KEYWORDS

natural farming, vegetable crops, marketing challenges, market supply chains, consumer awareness

Introduction

Globally, agriculture contributes to about 18% of the net emissions just from the production of crops. The post-farm-gate contribution in packaging, transportation, consumption, and wastage is over and above this contribution (Hannah Ritchie, 2020). Overall, it is estimated that conventional food systems impact about 26% of the global climate crisis. In India, there is a major challenge to food systems from a sustainability perspective of social, ecological, and economic proportions. This is also reflected by the frequent farmer protests linked to these aspects and the impact of climate change, which is experienced due to many factors (Hannah Ritchie et al., 2022).

The strategic shift toward diversified horticulture, especially vegetable cultivation, is recognized as a key driver for improving food and nutritional security, rural livelihoods, and sustainable agricultural intensification (Schreinemachers et al., 2018). India is the second largest vegetable-growing country in the world and holds 10.6% share in world's vegetable production. Its rich and diverse climate provides a large variety of vegetables, including potatoes, tomatoes, onions, eggplants, and cabbages. India is the largest producer of vegetables like ginger and okra, and the second largest in the case of vegetables like potatoes, onions, cauliflowers, brinjal, and cabbages (Lal, 2024). According to the National Horticulture Database (1st Advance Estimates) published by the National Horticulture Board for 2023-24, India has produced about 209.4 million metric tonnes of vegetables, with the area under cultivation being about 11.24 million hectares. The data also predicts increased production of vegetables like cabbage, cauliflower, pumpkin, tapioca, tomato, and others. This substantial production base offers India immense export opportunities. This convergence of global insights and India's unique production advantages underscores the transformative potential of vegetable cultivation as a sustainable strategy for achieving both economic and nutritional goals in agriculture (Konfo et al., 2024; Shraddha Bhardwaj et al., 2024; Shraddha Shukla et al., 2023). These factors, combined with the growing importance of achieving food and nutritional security, position vegetable farming as a critical element in India's agricultural sector. According to the *Dietary Guidelines* by the Indian Council of Medical Research (ICMR) (2024), it is recommended that every individual consume at least 400 g of vegetables daily. This includes 100 g of GLV, 250 g of other vegetables, and a portion of roots and tubers. The economic significance of vegetable consumption is linked to increased market demand, which directly influences farmers' cropping decisions. By aligning production with market needs, vegetables serve as high-value crops that enhance income opportunities for producers while simultaneously addressing the Zero Hunger goal (SDG 2 of the Sustainable Development Goals) (Vashishat et al., 2024; Agrawal et al., 2021).

Himachal Pradesh is a North Indian state known for its varied agro-climatic zones, supporting the cultivation of a broad spectrum of crops, particularly vegetables. Within Himachal Pradesh, the Mandi District stands out as a significant hub for vegetable cultivation, with food crops being a major source of livelihood for farmers. The data from 2021 to 2022 indicates that vegetable farming plays an essential role in the region's agricultural output, contributing significantly to its economy. A total of 7,931 ha was dedicated to vegetables (Department of Economics and Statistics, 2022). Mandi District's agricultural profile reveals that vegetables are vital for both subsistence and commercial agriculture, further reinforcing the link between vegetable farming and rural development in the region. In recent years, natural farming practices have emerged as an alternative to conventional methods, offering a more sustainable and cost-effective approach. These practices have proven transformative, particularly for small and marginal farmers who have benefited from reduced input costs due to the reliance on organic inputs like bio-fertilizers and pest management techniques (Bharucha et al., 2020). This shift not only helps protect the environment but also increases net income, making natural farming an increasingly attractive option for vegetable growers.

However, despite the potential for higher incomes from vegetable farming, farmers in Mandi and across Himachal Pradesh face numerous challenges. Traditional farming practices, along with market inefficiencies, restrict farmers from fully capitalizing on the benefits of vegetable farming. As consumers become more health-conscious and demand for chemical-free, organic produce rises, farmers practicing natural farming find themselves in a position to tap into premium markets. This trend has enabled them to command higher prices for their produce, contributing to a noticeable improvement in their financial stability (Nayak et al., 2020; Chandrashekar, 2010; Yadav et al., 2013). Yet, challenges remain, particularly in terms of market access, transportation, and the availability of specialized markets that cater to natural or organic produce. Despite these hurdles, natural farming is gradually reshaping the agricultural landscape in Himachal Pradesh by improving farmers' incomes while promoting sustainability.

Marketing vegetable crops is a complex endeavor that involves various stakeholders, including producers, intermediaries, and retailers. The efficiency of the marketing supply chains chosen by farmers has a direct impact on their income and the sustainability of their livelihoods (Negi and Anand, 2015). In districts like Mandi, where smallholder farming is prevalent, the lack of streamlined marketing systems can significantly hinder the potential benefits of vegetable cultivation. Farmers often face obstacles such as high transportation costs, a lack of proper market information, and intermediaries who take a significant share of profits. As a result, optimizing these marketing supply chains is critical for ensuring that farmers can maximize their earnings from vegetable production (Chand, 2012).

This research paper aims to investigate the production and marketing challenges faced by vegetable farmers in the Mandi District of Himachal Pradesh state in India, with a particular focus on those practicing natural farming. By examining these issues, the study intends to provide insights into how natural farming practices can be integrated into the existing agricultural framework, ultimately leading to more sustainable and profitable outcomes for farmers. The study also highlights the broader implications for rural development and food security, emphasizing the role of sustainable agricultural practices in enhancing the livelihoods of farmers and promoting long-term environmental health. This research focuses specifically on the *Production and Marketing of Vegetable Crops Grown under Natural Farming: a Case Study of Mandi District in Himachal Pradesh*, offering

valuable insights into the opportunities and challenges that shape the livelihoods of vegetable farmers in this region.

Materials and methods

Subhash Palekar Natural Farming (SPNF), as adopted by farmers surveyed, follows a natural farming approach utilizing locally available biological resources for crop production and protection. Core interventions under SPNF include *Beejamrit* (a seed treatment formulation prepared from cow dung, cow urine, lime, and forest soil), *Jeevamrit/Ghanjeevamrit* (a microbial culture used as a biostimulant to enhance soil microbial activity and nutrient cycling), *Achhadan* (biomass mulching to conserve moisture and organic matter), and *Waaphasa* (ensuring optimal soil aeration and moisture balance for plant roots). These interventions are designed to regenerate soil health, minimize dependency on synthetic inputs, and strengthen agroecological balance. The biopesticide formulations like *Neemastra*, *Brahmastra*, and *Agniastra*—prepared using cow urine, neem leaves, green chili, garlic, and other botanicals—were used periodically to manage pests under SPNF.

> *"A sustainable food system (SFS) is a food system that delivers food security and nutrition for all in such a way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised. This means that: – It is profitable throughout (economic sustainability); – It has broad-based benefits for society (social sustainability), and – It has a positive or neutral impact on the natural environment (environmental sustainability")* (FAO, 2018).

The SPNF approach aligns with the broader vision of transitioning toward a Sustainable Food Systems Platform for Natural Farming (SuSPNf) by promoting ecological integrity, reducing the carbon footprint of agriculture, and improving farm-level resilience. By eliminating external inputs and reducing water usage, SPNF fosters self-reliance among farmers and enhances agrobiodiversity, which is vital for climate adaptation. The circular use of on-farm resources contributes to closed-loop nutrient cycles and reduced pollution, making SPNF a practical model for food system transformation, especially in resource-constrained hill agriculture contexts like Himachal Pradesh.

Study area

The Mandi district can be found between latitudes 31°13′50″ and 32°04′30″ north and longitudes 76°37′20″ and 77°23′15″ east. On the northwest, it is bordered by Kangra, and on the west, by Hamirpur and Bilaspur. The majority of the population in the Mandi district is dependent on agriculture for their livelihood. Mandi district ranks third for the production of vegetables (226,725 tons) and second for the area under vegetables (11,109 ha) (Department of Economics and Statistics, 2018).

Sampling procedure

Selection of the study area and sampling design

Most districts in Himachal Pradesh engage in the practice of natural farming. Himachal Pradesh's Mandi district was specifically chosen for this study. The farmers who practice natural farming were ultimately chosen using a simple random sampling design. From the Project Director of ATMA, Mandi, a list of farmers engaged in Subhash Palekar Natural Farming (SPNF) was initially obtained. Following that, 40 farmers were chosen at random from each of the three blocks of Sundernagar, Karsog, and Balh, based on their natural farming experience and progress. A total of 120 farmers were therefore chosen as a sample for the study (Figure 1).

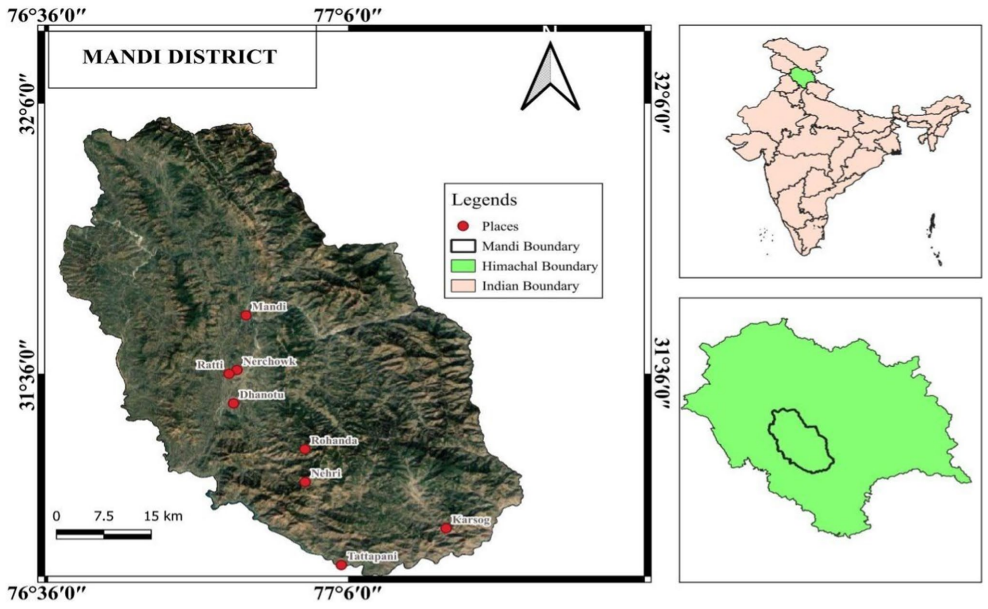

FIGURE 1
Map of the study are demonstarting the sample area.

Selection of market intermediaries

The study determined the sample size of market functionaries based on information obtained from the agricultural produce market committee office. As a result, four main markets were chosen. Shimla, Solan, Chandigarh, and Delhi markets were selected purposively. Further, to investigate different aspects of the four vegetables' output marketing, a total sample size of 80 traders was formed by randomly selecting five local traders, five commission agents, five wholesalers, and five retailers from each market.

Distribution of natural farmers by size of their landholding among the sampled farmers

To analyze the data, all respondents were divided into three groups based on the size of their landholdings: marginal (<1 ha), small (1–2 ha), and medium (2–4 ha). Table 1 shows how the sample households were distributed based on their holding size.

Analytical framework for marketing performance

Marketing cost

The marketing costs were calculated by combining the costs incurred by each marketing functionary participating in the supply chain process of major vegetable production. The amount spent on marketing differed depending on various factors such as the type of specific marketing activities, the type of marketing institutions, and the location of marketing. The intermediaries marketing costs comprised costs for packaging materials, fees for loading and unloading, transportation costs, commission charges, and taxes (Acharya and Agarwal, 2016).

$$TCm = Cg + \sum_{i=1}^{n} MCi$$

Where,
TCm = Total cost of vegetable marketing.
Cg = Cost paid by the grower in the marketing of his produce.
MCi = Marketing costs incurred by an ith middleman.

Marketing margins

Marketing margin analysis examines price variations at various stages of the marketing chain within the same timeframe. It evaluates the share of the final selling price captured by a specific agent in the marketing chain, often expressed as a percentage of the final price or the price paid by the end consumer (Thakur et al., 2023). In this study, marketing margins were employed as a key indicator for assessing market performance (Ghorbani, 2008). The marketing margin represents the difference between the farm-gate price, which is the price paid to the initial seller, and the retail price, or the price paid by the final consumer (Abankwah et al., 2010).

For this research, marketing margins were computed by calculating the absolute margin, where the cost price (including purchase price and marketing costs) is subtracted from the selling price of peas by a market agent. Several factors influence the size of marketing margins in different agricultural output marketing supply chains for peas, including the length of the marketing chain, the number of economic activities involved, and the profit expectations of each marketing entity. To calculate the percentage of marketing margins received by each intermediary in the marketing process, the formula provided by Acharya and Agarwal (2016) was applied.

$$\text{Ami} = \text{PRi} - \left(\text{Ppi} + \text{Cmi}\right)$$

Where,
Ami = Absolute margin of middlemen.
PRi = Total value of receipts per unit (sale price).
Ppi = Purchase value of goods per unit.
Cmi = Cost incurred on marketing per unit.

Price spread

The difference between the price paid by the consumer and the price received by the producers was the marketing margin, or price spread. Generally the economic efficiency of a marketing system is measured in terms of price spread. The smaller the price spread, the greater the efficiency of the marketing system, as suggested (Acharya and Agarwal, 2016).

Producer's share in consumer's rupee: It is the price received by the producer expressed as a percentage of the retail price (i.e., the price paid by the consumer). The producer's share in the consumer's rupee has been worked out as under:

$$PS = \frac{Pf}{Rp} \times 100$$

Where,
PS = Producer's share in consumer's rupee.
PF = Price received by the farmer per unit of output.
RP = Retail price per unit of output.

Marketing efficiency

Marketing efficiency of the marketing supply chains: in the case of marketing supply chains, the marketing efficiency is concerned with

TABLE 1 Distribution of sample households according to their land holdings.

S. no.	Category of farmer	Size of landholding (ha)	Number of farmers	Percentage of farmers	The average size of landholding (ha)
1	Marginal	< 1	89	74.17	0.58
2	Small	1–2	24	20.00	1.22
3	Medium	2–4	07	05.83	2.33

the movement of goods from producer to consumer at the lowest possible cost consistent with the provision of services desired by the consumers. The marketing efficiency of various supply chains in the study area has been computed by using Acharya's method (Acharya and Agarwal, 2016), as follows:

$$ME = \frac{RP}{MC + MM} - 1$$

Where,
ME = Marketing efficiency.
RP = Retailer's price.
MC = Total marketing costs.
MM = Total marketing margins.

Analytical framework for factors influencing choice

Multinomial logit regression model

We used a multinomial logistic regression model to assess farmers' preferences for agricultural output marketing supply chains. We employed this technique because farmers in the study regions have more than two options for marketing their farm produce. The model plays a significant role because, through this choice, the method can value multiple marketing supply chains. To examine the factors influencing their choice of marketing supply chains, an MNL model was employed. The MNL model is commonly used when there are several alternatives for the variable being explored (Bardhan et al., 2012; Martey et al., 2012; Delong et al., 2019; Asante and Weible, 2020; Goncalves et al., 2022). This technique is suitable for analyzing responses that are not ordered and involve more than two options (Chung et al., 2011; Mgale and Yunxian, 2020; Olutumise, 2022). Furthermore, based on the conceptual framework and previous empirical research on market supply chain selection, several relevant explanatory variables with potential impact on the choice of marketing supply chains were identified and incorporated into the multinomial logit analysis (Panda and Sreekumar., 2012; Gelaw et al., 2016; Pham et al., 2019; Thakur et al., 2022a, 2022b).

According to Greene (2003) and Gujarati and Porter (2009), we assumed the probability (Pij) that the ith farmer will choose the jth agricultural output marketing supply chain among two available options. Consequently, the multinomial logistic regression model was used to estimate the probability of a farmer selecting a specific alternative j in the following manner:

$$P_{ij} = \frac{\exp\left(\beta_j x_i\right)}{1 + \sum_{j=1}^{4} \exp\left(\beta_j x_i\right)} \text{for j} = 1,2 \quad (1)$$

Where xi is a distinct characteristic of the ith farmer, while βj represents a set of estimated regression parameters associated with the jth alternative. It is important to note that there are two agricultural output market supply chains available for selection in the choice set. In the multinomial logit model, the coefficients of the independent variables for the reference or omitted category are assumed to be zero. To determine the probability of selecting the base category, the following equation is employed:

$$P_i\left(j = 1 / x_i\right) = \frac{1}{1 + \sum_{j=1}^{4} \exp\left(\beta_j x_i\right)} \quad (2)$$

The probabilities of the ith farmer belonging to the remaining one category (where j = 2) can be computed using the following approach:

$$P_i\left(j = mIx_i\right) = \frac{\exp\left(\beta_j x_i\right)}{1 + \sum_{j=2}^{4} \exp\left(\beta_j x_i\right)} \text{for m} > 1 \quad (3)$$

To assess the impact of various characteristics on the likelihood, the marginal effects can be determined by differentiating Equation 1 concerning the covariates in the following manner:

$$\frac{\partial P_j}{\partial x_j} = P_j\left[\beta_j - \sum_{j=0}^{4} P_j \beta_j\right] = P_j\left[\beta_j - \beta\right] \quad (4)$$

Pj represents the probability that the vegetable producer will choose marketing supply chain j, while, βj is a vector of regression parameter estimates specifically associated with option j.

The empirical Multinomial Logit Regression model incorporates the following variables that influence the farmers' selection of marketing supply chains for their pea produce:

$$\begin{aligned}\text{Pij} = 1\text{n}\left(\text{Pi} / \text{Pj}\right) = {} & \beta 0 + \beta 1\ \text{Education} + \beta 2\ \text{Farming Experience} \\ & + \beta 3\ \text{Storage Facility} + \beta 4\ \text{Distance} + \beta 5\ \text{Financial Urgency} \\ & + \beta 6\ \text{Payment in Advance} + \beta 7\ \text{Premium Price} \\ & + \beta 8\ \text{Specialized Market}\end{aligned}$$

The variables that need to be estimated in the model are β0… β8.

Pij represents the probability that farmer i chooses marketing supply chain j for their agricultural output.

Where, j = 1 for producer→ retailer→ consumer, j = 2 for producer→ local trader→ wholesaler→ retailer → consumer. In the present research study, we used STATA-12 software to estimate the empirical model.

Analytical framework for marketing constraints

Marketing problems: to study the various problems associated with the production and marketing of natural farming, it was assumed that the extent of a particular problem varies from place to place and farmer to farmer. The multiple responses of producers reporting various problems were taken into consideration for analysis.

Chi-square test: To test whether there was any significant difference among marginal, small, and medium farms of Mandi for the problems faced by them. The chi-square test in the (m x n)

contingency table was applied (Turhan, 2020), where m and n are the number of marketing problems faced by the farmers of natural farming in Mandi district. The detail of the approximate chi-square test is given as under:

$$\sum_{i=1}^{K}\frac{(O_i-E_i)^2}{E_i}\chi^2(K-1)d.f.$$

Where,
O = Observed values.
E = Expected values.
K = number of farm size groups.

Result and discussion

Marketing supply chains serve as critical pathways that facilitate the movement of commodities from producers to consumers. The structure and efficiency of these supply chains can significantly impact the profitability and viability of agricultural products, particularly vegetables. The choice of marketing supply chain can influence not only the price received by producers but also the end price paid by consumers. Factors such as the type of commodity, the distance between suppliers and consumers, and the presence of various marketing functionaries all contribute to the characteristics of these supply chains.

The following marketing supply chains for vegetable marketing were observed in the Sundernagar, District Mandi, Himachal Pradesh, India, market.

Supply chain – A (SC - A): Producer – Consumer.

Supply chain – B (SC - B): Producer - Wholesaler – Retailer – Consumer.

Supply chain – C (SC - C): Producer- Local Trader – Wholesaler – Retailer - Consumer.

Quantity of vegetables marketed through various supply chains: Quantity of vegetables sold across various marketing supply chains (Table 2). Farmers sell more than 67 percent of their produce through SC - C producers — local traders— wholesalers— retailers — consumers. Overall, 65.99% (French bean), 63.86% (Pea), 70.25% (Tomato), and 68.18% (Cauliflower) were disposed of via SC - C followed by SC - B, and SC - A. Wholesalers and local traders send more than 85% of the vegetables to the country's distance market and the popular markets are Shimla, Chandigarh, and Delhi (Figures 2, 3).

Marketing cost and margin of different functionaries in the various marketing supply chain

The marketing costs and margins involved for different functionaries in the marketing supply chains of French bean, pea, tomato, and cauliflower have been thoroughly analyzed. These costs vary by crop and marketing supply chain, and they are critical in understanding the financial implications for producers, local traders, wholesalers, and retailers. The breakdown of these costs is as follows:

In Table 3, marketing cost incurred by producer: the marketing costs borne by producers can vary significantly across different supply chains. Direct sales to consumers (SC - A) generally involve the lowest costs, as there are no intermediary fees. For example, French bean producers incur Rs. 65 in SC - A, while in SC - B, which involves wholesalers, this cost rises to Rs. 112. Similarly, for peas, the cost in SC - A is Rs. 55, but it increases to Rs. 115 in SC - B. For other vegetables like tomato and cauliflower, the costs follow similar patterns. This trend highlights that longer marketing chains lead to increased costs for producers due to additional expenses like transportation and storage (Pingali et al., 2005). Similar findings are observed in studies emphasizing that intermediaries significantly raise marketing expenses for smallholders in developing economies (Govindasamy and Nayga, 1996).

Marketing Costs Incurred by Local Traders: Local traders, who play a key role in aggregating produce and selling it to wholesalers, also face substantial marketing costs, particularly in more extended supply chains like SC - C. For French beans, local traders bear costs of Rs. 33,392, primarily due to mandi fees and commission charges, while for peas, the cost is Rs. 29,446. These costs are a reflection of the complexity involved in transporting and handling agricultural produce through the marketing chain. Similar studies have demonstrated the significant transaction costs faced by traders when engaging in wholesale markets, which are then passed on to consumers (Chand, 2012).

Marketing Costs Incurred by Wholesalers: Wholesalers, key intermediaries in supply chains B and C, face substantial costs due to fees, storage, and transport expenses. For example, in SC - B, the

TABLE 2 Quantity of vegetables marketed through various supply chains (per cent).

Marketing supply chains	Marketing intermediaries	(%) Quantity marketed			
		French bean	Pea	Tomato	Cauliflower
SC – A	Producer-Consumer	11.54	5.36	8.56	9.25
SC – B	Producer-Wholesaler-Retailer-Consumer	22.47	30.78	21.19	22.57
SC - C	Producer-Local trader-wholesaler-Retailer-Consumer	65.99	63.86	70.25	68.18

wholesaler incurs Rs. 34,629 for French beans, while in SC - C, this cost reduces slightly to Rs. 32,954, likely due to more efficient handling at local trader levels. These results are consistent with other studies that show how wholesalers, despite playing an essential role in connecting producers to urban markets, bear significant financial burdens that impact the overall cost structure of agricultural marketing (Pingali et al., 2005).

Marketing Costs Incurred by Retailers: Retailers, who serve as the final link in the supply chain, typically incur the highest marketing costs but also enjoy the greatest margins. For French beans, for instance, the cost in SC - B is Rs. 36,060, and in SC - C, it is Rs. 38,351. Retailers also earn Rs. 150 per quintal for French beans, indicating the high margins at this stage of the chain. This reflects findings from other studies that emphasize the significant value-added services retailers provide, such as better storage and convenient access for consumers, which justify their higher returns (Govindasamy and Nayga, 1996).

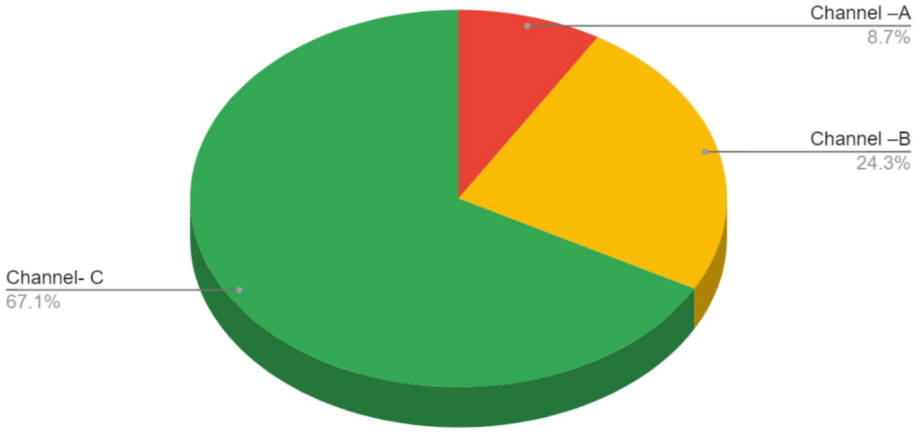

FIGURE 2
Quantity of vegetables marketed through various supply chains.

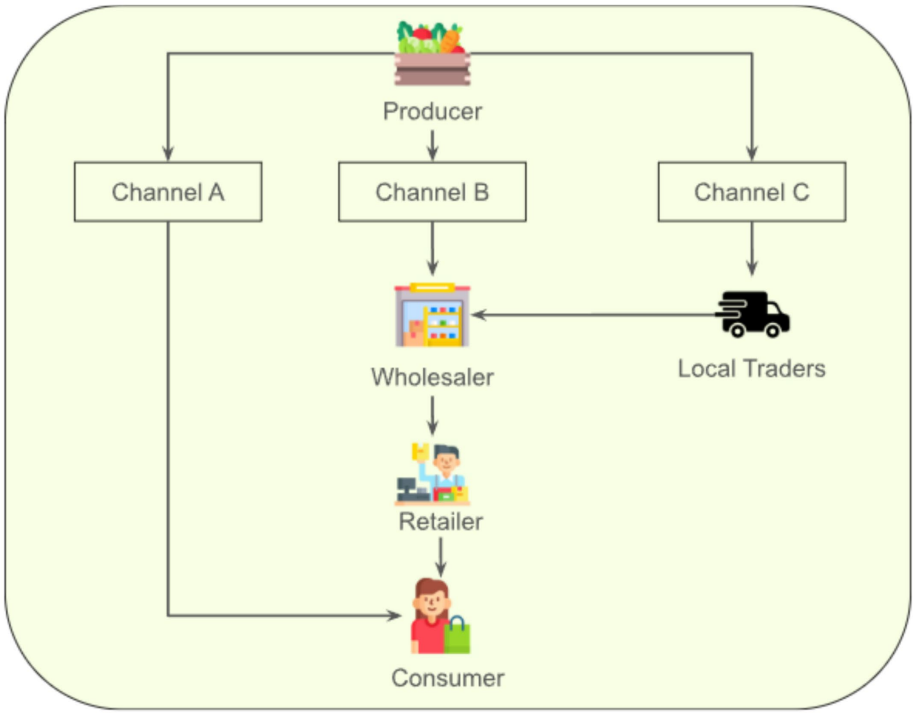

FIGURE 3
Major vegetables marketed through different marketing supply chain by natural farmers.

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TABLE 3 Marketing costs and margin of different functionaries of four major crops in Mandi market of Himachal Pradesh (rupees per quintal).

S. No.	Particulars	French bean			Pea			Tomato			Cauliflower		
		A	B	C	A	B	C	A	B	C	A	B	C
I.	Marketing cost incurred by producers												
	Net price received by farmer	2,881	3,229	3,043	3,270	3,012	2,835	2,210	1906	1800	1900	1805	1711
	Marketing cost	65	112	100	55	115	86	170	190	180	80	105	100
	Farmer's selling price	2,946	3,341	3,143	3,325	3,127	2,921	2,380	2096	1980	1980	1910	1811
II.	Marketing cost incurred by trader												
	Gross price paid by trader			3,143			2,921			1980			1811
	Marketing cost			334			294			214			188
	Trader margin			80			65			40			40
	Trader selling price/wholesaler purchase price			3,557			3,280			2,234			2039
III.	Marketing cost incurred by wholesaler												
	Gross price paid by wholesaler		3,341	3,557		3,127	3,280		2096	2,234		1910	2039
	Marketing cost		346	330		318	348		323	344		228	228
	Wholesaler Margin		120	120		160	120		100	80		70	55
	Wholesaler selling price/retailer purchase price		3,807	4,006		3,605	3,749		2,520	2,658		2,208	2,322
IV.	Marketing cost incurred by retailer												
	Gross price paid by retailer		3,807	4,006		3,605	3,749		2,520	2,658		2,208	2,322
	Marketing cost		361	384		373	380		273	284		226	242
	Retailer margin		150	150		200	200		150	140		80	75
	Retailer selling price		4,318	4,540		4,179	4,328		2,943	3,082		2,514	2,639
V.	Consumer' purchase price	2,946	4,318	4,540	3,325	4,179	4,328	2,380	2,943	3,082	1980	2,514	2,639

Price spread of four major crops among different marketing supply chains

In Table 4, the analysis of price spreads for four major crops—French bean, pea, tomato, and cauliflower—across various marketing supply chains (A, B, and C) reveals significant differences in producer profitability and marketing efficiency.

For French bean market, producer prices ranged from Rs. 2,881 to Rs. 3,229. SC - A stood out with the highest producer share at 97.79%, offering minimal marketing costs (2.21%). Meanwhile, SC - C presented the highest gross marketing margin (32.97%), indicating greater profitability for intermediaries. Although SC - A had a lower volume of sales, it proved to be the most efficient supply chain due to its reduced costs and high producer returns.

For pea market exhibited a producer price range of Rs. 2,835 to Rs. 3,270. SC - A again led with a remarkable producer share of 98.35%, similar to the findings for French bean. The gross marketing margins were highest in SC - C (34.50%), while SC - A maintained the lowest marketing costs (1.65%). Thus, while SC - C offered better margins for intermediaries, SC - A remained the top choice for producers seeking maximum returns.

For tomato, producer prices fluctuated between Rs. 1800 and Rs. 2,210. SC - A retained the highest producer share at 99.86%, emphasizing its efficiency despite lower sales volumes. Gross marketing margins peaked in SC - C (41.59%), underscoring its profitability for traders. This trend highlights a consistent pattern: while intermediary supply chains may offer higher margins, direct sales supply chains maximize producer returns.

For Cauliflower market showed producer prices ranging from Rs. 1711 to Rs. 1900. Once again, SC - A led with a substantial producer

TABLE 4 Price spread of vegetable crops among the different marketing supply chains in Mandi district.

S. no.	Particulars	French bean			Pea			Tomato			Cauliflower		
		A	B	C	A	B	C	A	B	C	A	B	C
1	Producer price (Rs.)	2,881	3,229	3,043	3,270	3,012	2,835	2,210	1906	1800	1900	1805	1711
2	Consumer's price (Rs.)	2,946	4,318	4,540	3,325	4,179	4,328	2,380	2,943	3,082	1980	2,514	2,639
3	Gross marketing margin (GMM) (Rs)	0	1,089	1,497	0	1,167	1,494	0	1,036	1,282	0	708	928
4	Marketing cost (Rs.)	65	819	1,147	55	807	1,109	170	786	1,022	80	558	758
5	Marketing margin (Rs.)	0	270	350	0	360	385	0	250	260	0	150	170
6	Gross marketing margin (GMM) (%)	0	25	33	0	28	35	0	35	42	0	28	35
7	Marketing cost (%)	2	19	25	2	19	26	7	27	33	4	22	29
8	Net marketing margin (%)	0	6	8	0	9	9	0	9	8	0	6	6
9	Producer's Share	98	75	67	98	72	66	93	65	58	96	72	65
Marketing efficiency													
10	Consumer's price (Rs.)	2,946	4,318	4,540	3,325	4,179	4,328	2,380	2,943	3,082	1980	2,514	2,639
11	Net marketing margin (%)	0	6	8	0	9	9	0	9	8	0	6	6
12	Marketing efficiency	44	3	2	59	3	2	13	2	1	24	3	2

share of 95.96% and minimal marketing costs (4.04%). SC - C had the highest gross marketing margin (35.16%), yet it underscored the trade-off between producer share and intermediary profitability.

Across all four crops, SC - A consistently emerged as the most efficient marketing supply chain, providing the highest producer shares and lowest marketing costs. While intermediary supply chains such as SC - C may yield higher gross margins, they come at the expense of reduced returns for producers. This comparative analysis suggests that direct marketing supply chains are preferable for producers aiming to maximize profitability while navigating the complexities of agricultural markets.

Maximum likelihood estimate

The Table 5 presents the maximum likelihood estimates for various factors influencing the selection of marketing supply chains among vegetable farmers in Himachal Pradesh. A multinomial logistic regression analysis was used to assess these factors, focusing on SC - B (Producer-Wholesaler-Retailer-Consumer) and SC - C (Producer-Local Trader-Wholesaler-Retailer-Consumer), with SC - A (Producer-Consumer) serving as the base or reference category.

The coefficients and *p*-values indicate the likelihood that a farmer will choose a given supply chain over SC - A, with several variables demonstrating significant impacts. Distance to Market emerges as a key factor, with positive coefficients for both SC - B and SC - C, indicating that as the distance to the market increases, farmers are more likely to opt for supply chains involving wholesalers and local traders, rather than selling directly to consumers. Farming experience also plays a critical role, particularly in SC - B, where more experienced farmers are more likely to use wholesalers and retailers. The availability of storage facilities significantly reduces the likelihood of farmers choosing intermediary-heavy supply chains, as farmers with access to storage can preserve their produce and wait for better market conditions. Financial urgency also influences supply chain choice, with farmers under immediate financial pressure more likely to engage in SC - B, although this factor is not significant for SC - C. Advance payment is marginally significant for SC - C, indicating that farmers may prefer local traders when the option of advance payments is available. On the other hand, premium price shows a significant negative influence on both SC - B and SC - C, suggesting that when farmers expect to receive premium prices, they are less likely to use these supply chains and more likely to engage in direct-to-consumer sales, where they can

TABLE 5 Likelihood estimates for factors affecting choice of agricultural output marketing supply chain of various vegetable crops.

Variables	SC - B		SC - C	
	Coefficient	*p*-value	Coefficient	*p*-value
Distance to market	0.037** (0.018)	0.04	0.1367** (0.055)	0.03
Education	0.0611 (0.112)	0.583	0.0369 (0.118)	0.754
Farming experience	0.1357*** (0.04)	0.004	0.2525 (0.263)	0.338
Storage facility	−2.6922** (0.996)	0.007	−1.8354** (0.8792)	0.037
Financial urgency	1.0726** (0.464)	0.03	0.7562 (0.808)	0.349
Advance payment	−0.4681 (0.758)	0.536	1.6565* (0.912)	0.07
Premium price	−1.3976** (0.766)	0.068	−2.2632** (0.8574)	0.013
Specialized market	−0.5474 (0.7801)	0.483	−0.6245 (0.8577)	0.467
Constant	6.0219 (8.6109)	0.484	0.5184 (9.159)	0.955
N	120			
LR chi square	31.57			
Prob > chi square	0.0003			
Pseudo R^2	0.37			
Log likelihood	−62.35			

*, **, and *** significant at 1, 5, and 10% significant level respectively; standard errors are in parentheses; producer to consumer (supply chain-A is used as the base category).

capture a greater share of the market price. Variables such as education and the presence of a specialized market were not found to significantly affect the choice of marketing supply chains. The overall model, indicated by an LR chi-square value of 31.57 and a pseudo R^2 value of 0.37, shows that the factors included in the analysis explain 37% of the variability in marketing supply chain choices. In summary, distance to market, farming experience, storage facility availability, financial urgency, and advance payment options are key factors influencing the selection of marketing supply chains, with farmers facing logistical challenges or financial urgency more likely to choose intermediary-based supply chains, while those with storage access or premium price expectations prefer direct-to-consumer sales. To compute the probabilities and marginal effects in the multinomial logit model, we used Equations (1–4) as specified in the methodology section. These equations estimate the probability that a farmer selects a particular supply chain alternative, and calculate the marginal effect of each explanatory variable on the probability of selecting that supply chain.

Marginal effects estimate

The Table 6 presents the marginal effects of various factors influencing farmers' choice of agricultural output marketing supply chains for vegetable crops, specifically SC - B (Producer-Wholesaler-Retailer-Consumer) and SC - C (Producer-Local Trader-Wholesaler-Retailer-Consumer), with SC - A (Producer-Consumer) as the base category. Distance to Market is a critical factor, with significant positive impacts on the likelihood of farmers choosing SC - B (coefficient = 0.037, $p = 0.04$) and SC - C (coefficient = 0.1367, $p = 0.03$). As the distance from the market increases, farmers are more likely to rely on intermediaries like wholesalers and local traders, rather than selling directly to consumers. This aligns with the findings of Hernández et al. (2007), who observed that logistical challenges such as longer distances compel farmers in Guatemala to prefer intermediary supply chains to reduce transportation costs and risks. Education shows a marginal influence on marketing supply chain selection, with slightly positive coefficients for both SC - B and SC - C, although it is not a significant determinant in either case. However, Bandiera and Rasul (2006) argue that educated farmers are better equipped to navigate complex marketing systems, which can indirectly influence their decisions to use intermediary-heavy supply chains, as knowledge of market dynamics helps them manage the associated risks. Farming experience is particularly important for SC - B (coefficient = 0.1357, $p = 0.004$), where experienced farmers prefer to sell their produce through wholesalers and retailers, likely due to their familiarity with structured supply chains. The marginal effect for farming experience in Supply Chain C is not significant ($p = 0.979$), suggesting that farming experience may not influence the choice of this supply chain. This finding is supported by Pingali et al. (2005), who suggest that more experienced farmers have better market connections and are more comfortable managing interactions with intermediaries. The availability of storage facilities significantly reduces the likelihood of farmers using intermediary-heavy supply chains. For SC - B, the coefficient is −2.6922 ($p = 0.007$), and for SC - C, it is −1.8354 ($p = 0.037$). Addition to storage facilities significant for SC-B, Farmers with access to storage can hold their produce and wait for better market conditions, reducing their reliance on intermediaries for quick sales. This is in line with Barrett (2008), who observed that smallholders with assets like storage facilities have greater flexibility in choosing marketing supply chains.

Financial urgency significantly affects the choice of SC - C (coefficient = 1.0726, $p = 0.03$), as farmers facing immediate financial needs are more likely to sell through local traders. In Supply Chain Dynamics and Food Inflation in India, smallholder farmers often receive minimal consumer pricing due to multiple intermediaries, incentivizing them to choose quicker but lower-return market chains (Kundu, 2019). Financial urgency does not significantly impact the choice of SC - B, suggesting that wholesalers are not typically associated with providing immediate cash flow relief. Advance payment options

TABLE 6 Marginal effects estimate for factors affecting choice of agricultural output marketing supply chain of various vegetable crops.

Variables	SC - B		SC - C	
	Marginal effect	*p*-value	Marginal effect	*p*-value
Distance to market	0.0043** (0.00159)	0.021	0.0855** (0.0415)	0.04
Education	0.0306** (0.0138)	0.028	0.0325*** (0.01202)	0.006
Farming experience	0.0263** (0.0123)	0.04	0.0008 (0.0302)	0.979
Storage facility	−0.1731 (0.0901)	0.055	−0.2065** (0.1018)	0.043
Financial urgency	−0.0451 (0.0960)	0.639	0.1133*** (0.03732)	0.001
Advance payment	0.0663*** (0.02015)	0.005	0.1965* (0.1057)	0.063
Premium price	−0.1608* (0.0868)	0.064	−0.1654** (0.0706)	0.036
Specialized market	−0.0179 (0.10205)	0.861	−0.0458 (0.1215)	0.706

***, **, and * significant at 1, 5, and 10% significant level respectively; standard errors are in parentheses; producer to consumer (supply chain-A is used as the base category).

also play a role, particularly in SC - C, where the coefficient is 1.6565 ($p = 0.07$), suggesting that farmers are more likely to sell through local traders when advance payment arrangements are available. Pingali et al. (2005) similarly found that the availability of credit or advance payments incentivizes farmers to engage with intermediaries.

The expectation of a premium price has a negative impact on both SC - B (coefficient = −1.3976, $p = 0.068$) and SC - C (coefficient = −2.2632, $p = 0.013$), indicating that farmers who expect higher prices for their produce prefer to sell directly to consumers, where they can capture a greater share of the final price. Gandhi Vasant and Namboodiri (2004) also found that farmers who can command premium prices for fruits and vegetables in markets like Ahmedabad, Chennai, and Kolkata prefer direct marketing to maximize profits. In terms of specialized markets, the coefficients were not statistically significant for either supply chain, suggesting that the availability of niche markets does not substantially influence farmers' decisions in this context. This is likely because vegetables are widely consumed and sold, making them less dependent on specialized marketing arrangements.

Marketing problems faced by the farmers

The study revealed a range of critical marketing challenges faced by vegetable growers practicing Subhash Palekar Natural Farming (SPNF) in Mandi district. These problems, evaluated across different farm sizes—marginal, small, and medium—highlight systemic barriers affecting market access, pricing, and overall profitability.

A substantial proportion of respondents (77.50%) identified the lack of dedicated markets for natural farming (NF) produce as a major concern. This issue was most prominent among medium farmers (100%), followed by small (79.17%) and marginal farmers (75.28%). The absence of specialized markets limits the visibility and demand for natural produce, often forcing farmers to sell through conventional channels where natural farming (NF) products are not distinctly recognized or valued. A similar recommendation was made by Vashishat et al. (2021) in their study on the adoption and challenges of natural farming in Sirmour district of Himachal Pradesh, where they emphasized the need for market differentiation and support NF produces. Approximately 71.67% of farmers reported that they do not receive fair prices for their produce. This problem was more acute among medium (85.71%) and small farmers (83.33%), compared to 67.42% of marginal farmers. This pricing disparity may stem from market exploitation, low bargaining power, and lack of certification or consumer awareness of SPNF benefits. Azam et al. (2019) also found that marketing challenges vary according to farm size in the study area. They recommended that marketing policies should be framed based on the size of the farm.

An overwhelming 67.50% of respondents expressed concern over wholesalers selling their produce without obtaining prior consent. This issue was uniformly distributed across farm sizes, suggesting systemic malpractice in the marketing chain and a lack of contractual transparency. 60% of all respondents reported paying high commissions to intermediaries, with the issue being most prevalent among medium farmers (85.71%). The Chi-square value of 10.27, significant at the 5% level, indicates that the burden of commission varies significantly with farm size. These charges reduce the net returns for farmers and add inefficiencies to the value chain.

Only 51.67% of farmers believed that consumers are adequately informed about SPNF products. This problem was especially acute for small (75%) and medium farmers (71.43%), compared to only 43.82% among marginal farmers. The statistically significant Chi-square value (9.18*) suggests that farm size plays a role in how this issue is perceived or experienced. Poor branding and limited public outreach further reduce the perceived value of natural farming produce. 34.17% of respondents cited inadequate transport as a barrier to effective marketing. Medium farmers (57.14%) reported this problem more than marginal (31.46%) and small farmers (37.50%). The Chi-square value of 8.58, also significant, reflects that transport constraints are unevenly felt across farm categories, potentially due to the geographical remoteness or scale of operations. Nearly 42.50% of the farmers expressed concern over not receiving timely or accurate market information. While this issue was relatively consistent across all farm sizes, marginal farmers (44.94%) reported it slightly more than others. This information gap contributes to poor decision-making, delayed market entry, and reduced income (Table 7).

Conclusion

The findings revealed that farmers predominantly rely on intermediary-based supply chains, especially SC - C (Producer - Local Trader - Wholesaler - Retailer - Consumer), which accounted for 63% of the total produce traded. Farmers in the study area face numerous challenges, including the lack of access to commodity-specific markets, unfair pricing mechanisms, and inadequate government support. Additionally, inadequate training, limited extension services,

TABLE 7 Marketing problems faced by natural farming producer in Mandi district (per cent).

Problems	Farm size				
	Marginal	Small	Medium	Overall	Chi square
Marketing Problems					
Higher commission	60.67	50.00	85.71	60.00	10.27*
Wholesalers not taking consent while selling	66.29	70.83	71.43	67.50	0.23
consumer awareness about SPNF produce	43.82	75.00	71.43	51.67	9.18*
Non availability of specialized market	75.28	79.17	100.00	77.50	4.17
Lack of transport facilities	31.46	37.50	57.14	34.17	8.58*
No fair price for produce in market	67.42	83.33	85.71	71.67	2.51
lack of inadequate information	44.94	33.33	42.86	42.50	1.90

*Significant at 5% level.

and poor market infrastructure further constrain their ability to receive fair prices for their produce.

The study underscores the need for improved market linkages, stronger institutional support, and agricultural policy reforms that facilitate direct marketing supply chains, allowing farmers to capture a higher share of the consumer price. Enhancing market information dissemination, providing better access to infrastructure, and addressing these marketing inefficiencies are crucial steps toward increasing the profitability and sustainability of vegetable crops grown under natural farming in the region. The research highlights the importance of developing a robust marketing system that supports natural farming, enabling farmers in the Northwest Himalayan region to realize the full potential of their produce while promoting sustainable agricultural practices. Further study has highlighted the significant role of short food supply chains (SFSC) as one of the most essential aspects of driving marketing efficiency.

An innovative approach being implemented in Himachal Pradesh is the SuSPNF (Sustainable Food system Platform for Natural Farming) inclusive of SFSC resulting in intensifying the local food system and empowering rural economy, initiated by the Government of Himachal Pradesh. This system provides a solution to the traditional, intermediary-heavy marketing supply chains. Sustainable Food System Platform for Natural Farming (SuSPNF) operates on four core principles: transparency, traceability, and true cost accounting, achieved through the use of advanced technology. This innovative platform holds great potential for transforming not only the agricultural marketing landscape in Himachal Pradesh but also paves an inspiring model to adopt across the country, offering farmers a more efficient, equitable, and sustainable way to market their produce (Himachal Headlines, 2024).

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. Divyanshu: Writing – review & editing, Investigation. RSP: Methodology, Project administration, Supervision, Writing – review & editing. RSC: Supervision, Writing – review & editing. ID: Writing – review & editing. SS: Methodology, Supervision, Validation, Writing – review & editing. PM: Writing – review & editing. RKV: Writing – review & editing.

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