Cornous Biology
Review Article

From cereals to horticulture: crop diversification trends, drivers and challenges in Himachal Pradesh

Sunaina Sharma, Priya Sharma, Sachin Upmanyu*

Department of plant sciences, school of life sciences, central university of Himachal Pradesh, Shahpur campus – 176206, Kangra (HP), India.

***Correspondence**
Sachin Upmanyu
sachinupmanyu1974@gmail.com

Volume: 3, Issue: 3, Pages: 1-13
DOI: https://doi.org/10.37446/corbio/ra/3.3.2025.1-13
Received: 21 May 2025 / Accepted: 3 September 2024 / Published: 30 September 2025

Himachal Pradesh is a small hill state of Northern India. The state has an extensive range of agro-climatic conditions, ranging from low foothills to snow-covered highlands. Most of state's population is dependent on agriculture for livelihood, making it state's largest economy. But over the past few years it has been observed that the state's agriculture is shifting from traditional cereal based cropping system to high value commodities like fruits, vegetables and particularly off-season vegetables. This shift in consumption pattern from cereals to horticultural crops was at beginning seen in few districts like Shimla, Solan, Kullu and Lahul and Spiti which later gained pace in 1990s and since has spread in low and mid hill districts. Crop diversification is a crucial approach that can reduce crop failure risk, generate employment opportunities, help in environmental preservation and most importantly boost farm revenue which can ultimately increase household income of small and marginal farmers. The factors like climate change, demand for horticultural crops, support from government institutions and various state or centre government policies/schemes/projects are promoting crop diversification in the state. This review aims to show the changes in land use pattern and cropping pattern in the state and how these changes have led to diversification from cereals to horticultural commodities. This review also explains the factors that facilitate diversification, impacts of diversification and various constraints faced by agricultural diversification in state.

Keywords: crop diversification, farm revenue, land use, cropping pattern

Introduction

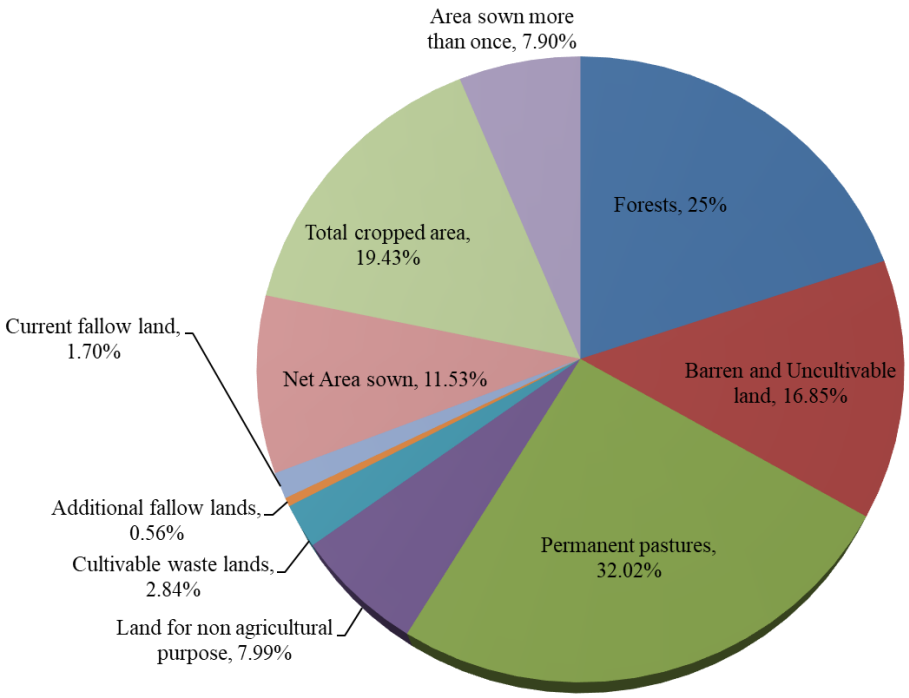
Himachal Pradesh also known as "Devabhoomi", or the abode of the Gods, is a small hill state located in the centre of Western Himalayas in Northern India, and is renowned for its rich cultural heritage and breathtaking scenery. The state lies between 75˚44'55" to 79˚04'20" East longitudes and 30˚22'44"to 33˚12'40"North latitudes (Singh & Kumar, 2014). It consists 55,673sq.km total geographical area with the population of 6,856,509 persons (Singh & Kumar, 2014). The majority of its population relies either directly or indirectly on agriculture for their livelihoods, making it the backbone of the state's economy (Singh et al., 2004). With 63% of the labor force in Himachal Pradesh directly or indirectly dependent on agriculture and it is also the state's largest industry and primary occupation (Kumar, 2017). Although, Himachal Pradesh has a total geographical area of 55,673sq.km but only 11% is suitable for farming (Sharma, 2011). In Himachal Pradesh, it has been observed that horticultural goods like fruits and vegetables are replacing cereal grain as primary source of nourishment. To a certain degree this change in consumption patterns led to a shift towards high value commodities, changes in customer's tastes, preferences and income (Reddy, 2009). Over the past few years, crop diversification in Himachal Pradesh has rapidly expanded towards high-value commodities such as fruits and vegetables, particularly off-season vegetables (Chaudhary & Singh, 2020). Given the wealth of natural resources available, crop diversification is crucial for agricultural development in Himachal Pradesh (Singh et al., 2020). Himachal is classified in four different zones on the basis of varied agro-climatic conditions (Barwal & Sharma, 2023).

1)Zone-I: Sub-mountain and low hills subtropical zone (upto 1100m). Consist of Una,Bilaspur, Hamirpur and parts of Sirmaur, Kangra, Solan and Chamba districts.
2) Zone-II: Mid-hills, high sub-humid zone (upto 1100-<2,000m). Covers major parts of Mandi and Solan and some parts of Hamirpur, Kangra (Palampur and Kangra tehsil), Shimla, Kullu, Chamba and Sirmaur districts.
3) Zone-III: High hills, temperate wet zone (upto 2,000-<3,000m). Major parts of Kullu and parts of Solan, Mandi, Chamba, Kangra and Sirmaur districts, Shimla district except Rampur tehsil.
4) Zone-IV: High hills, temperate dry zone (>3,000m). Kinnaur, Lahaul-Spiti and parts of Chamba district.

This vast range of Agro-climatic conditions with elevations ranging from 350 meters above mean sea level to over 8,000 meters has enormous potential for agricultural diversification through the production of wide range of grains, fruits, vegetables, flowers, aromatic and medicinal plants(Sarial, 2019).In Himachal Pradesh, crop diversification towards fruit and vegetable crops began in 1960s and picked up speed in the 1970s and 1980s, particularly in some regions of the districts of Shimla, Solan, Kullu and Lahul and Spiti(Sharma, 2005).Agricultural diversification from low value to high value crops began to pick up pace in the 1990s and has since spread to numerous additional regions in the low and mid-hill districts (Sharma, 2011). Diversification from staple consumables such as rice, wheat, coarse cereals to high value commodities like fruits and off-season vegetables becomes a crucial approach that can boost agricultural revenue, reduce crop failure risk, can help with poverty alleviation, employment opportunity, environmental preservation and most importantly, generate foreign exchange (Sharma, 2018).Considering the substantial changes occurring in the food preferences, farmers have a lot of opportunity to raise their standard of living in the high-value sector of agriculture (Gummagolmath et al., 2020)

Land utilization pattern in Himachal Pradesh

Any nation's pattern of land use dictates the type and extent of job opportunities, revenue and consequently the standard of living for its populace (Kumar, 2016). The agricultural economy of Himachal Pradesh is largely dependent on land resources, such as soil, land type and land availability, all of which define crop compatibility and have a significant impact on agricultural economy (Singh & Kumar, 2022).

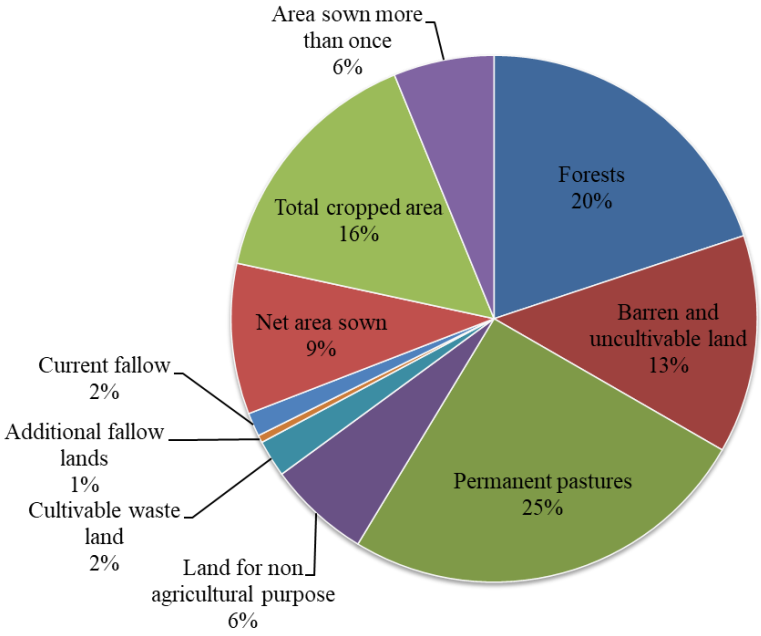


Source: Himachal Pradesh Government's Annual Season And Crop Report, 2021-2022

Figure 1. Classification of area under land utilization for the year 2021-22

According to Himachal Pradesh government's annual season and crop report for year 2021-2022, the state's land usage is systematically classified into a number of categories based on specific attributes intended for efficient utility and preservation. Of the 55,67,300 hectares or 55,673 sq km of state's total land area, 45,77,038 hectares have been

surveyed, leaving 9,90,262 hectares unsurveyed. A significant portion of this land area, which made up 17.79% of entire geographical region in the aforementioned year, is located in the districts of Kullu, Sirmour and Lahaul-spiti. The pie graph 1.1 shows classification of area under land utilization in Himachal Pradesh. The pie chart shows (Figure 1) that 11,44,097 hectares or 25% of reported area was covered by forests, whereas 7,71,053 hectares or 16.85% are made up of bare and uncultivable ground. Permanent pastures make up 14,65,525 hectares or 32.02% of the 3,65,546 hectares (7.99%) of land used for non agricultural purposes. There were 1, 29,852 hectares of cultivable waste lands (2.84%), additional fallow lands (0.56%) and existing fallows (1.70%). Furthermore, the area seeded more than once, which is calculated by subtracting the net area sown from the total area under cultivation, was 3,80,981 hectares in 2021-2022, compared to 3,61,724 hectares in the year 2020-2021.The total cropped area was 8,89,349 hectares and net area seeded was 5,27,625 hectares (1.53%).



Source: Statistical Abstract Of Himachal Pradesh 2023-24, Department Of Economics And Statistics Government Of Himachal Pradesh

Figure 2. Classification of area under land utilization for the year 2022-23.

However, according to the statistical abstract of Himachal Pradesh for the year 2023-24, 1,14,434 hectares (20%) of reported area is covered by forests, whereas 7,70,877 hectares or 13% are made up of bare and uncultivable ground. Permanent pastures make up14,58,486 hectares or 25% of the 3,61,686 hectares (6%) of land used for non-agricultural purposes. There are 1,30,599 hectares of cultivable waste lands (2%), additional fallow lands (1%) and existing fallows (2%). Furthermore, the area seeded more than once, which is calculated by subtracting the net area sown from the total area under cultivation, was 3,55,565 hectares in 2022-2023, compared to 3,80,981 hectares in the year 2021-2022. With a total cropped area of 8,87,632 hectares and 5,32,087 hectares (9%) of net area seeded, the state's land use dynamics exhibit a variety of agricultural activities and complexity (Figure 2)

Cropping pattern in Himachal Pradesh

The state Himachal Pradesh is gifted with varied agro-climatic conditions which range from low foot hills to snow bound high hills. According to Government of Himachal Pradesh & Economics and Statistics Department, 2024 the major crops grown in state are Wheat, Maize, Rice, Barley and Pulses which constitute nearly 80% of total area under cultivation. HP State Seed & Organic Produce Certification Agency in their annual report for year 2022-23 reported that during kharif season, the state's principal crops are paddy, maize, pulses and millets, out of which, around 88.4% cultivated area is covered by maize and paddy crops. Whereas in Rabi season the main crops are wheat, barley, gram and other pulses, out of which wheat and barley take up around 95.4% of the cultivated region. Thus, in both the seasons, these four crops make up over 90% of the total cultivated area. In past years, farmers of the state used to grow oilseeds and to a certain extent pulses, in various cereal-based cropping practices with little input expenditure leading to small-scale farming. However, as transportation and communication infrastructure have improved and agricultural innovations have occurred, farmers in some areas of state are switching towards fruits and vegetable cultivation which bring in a respectably high price and income for farmers (Gangwar & Singh, 2011). According to a study conducted in

the districts Kinnaur, Mandi and Shimla by Sood & Kumar (2022), vegetables are more productive than grain crops and pulses.

Table 1. Area (in 000′Hects.)

S. No	Crop	Year						
		2017-18	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**2023-24**
1	Maize	280.81	286.780	269.950	267.41	257.827	255.076	-
2	Paddy	71.61	71.810	65.717	68.46	65.757	68.992	-
3	Wheat	318.87	319.002	329.490	333.15	321.862	318.449	-
4	Barley	19.16	20.356	17.783	20.55	18.229	16.575	-
5	Ragi	1.82	1.720	1.76	0.58	1.13	1.15	-
6	Common millets	4.18	5.012	5.32	2.90	2.22	2.13	-
7	**Total cereals**	**696.45**	**704.68**	**690.02**	**693.05**	**667.025**	**662.372**	-
8	Total pulses	28.11	27.856	29.139	30.43	26.527	25.561	-
9	**Total food grains**	**724.56**	**732.536**	**719.159**	**723.48**	**693.552**	**687.933**	-
10	Total fruits	230.85	232.139	233.300	234.779	235.785	236.466	236.47
11	Total vegetables	78.68	94.555	101.24	102.55	101.921	102.585	92.30
12	**Total food crops**	**1034.09**	**1059.23**	**1053.699**	**1060.809**	**1031.258**	**1026.984**	-

Source: (i) Himachal Pradesh government annual season and crop report for year 2017-2023, Directorate of Land Records H.P.
(ii) Statistical abstract of Himachal Pradesh 2017-18.
(iii) Department of agriculture Himachal Pradesh.
(iv) Statistical year book Himachal Pradesh 2022-23, Department of economic & statistics Himachal Pradesh, Shimla.
(v) Statistical abstract of Himachal Pradesh 2023-24: data visualization.

Table 1 provides a detailed numerical picture of the cropping pattern in Himachal Pradesh from 2017–18 to 2023–24. The values show that the area under cereals and pulses has gradually declined over the years, reducing the total food crop area from 724.56 thousand ha in 2017–18 to 687.93 thousand ha in 2022–23.

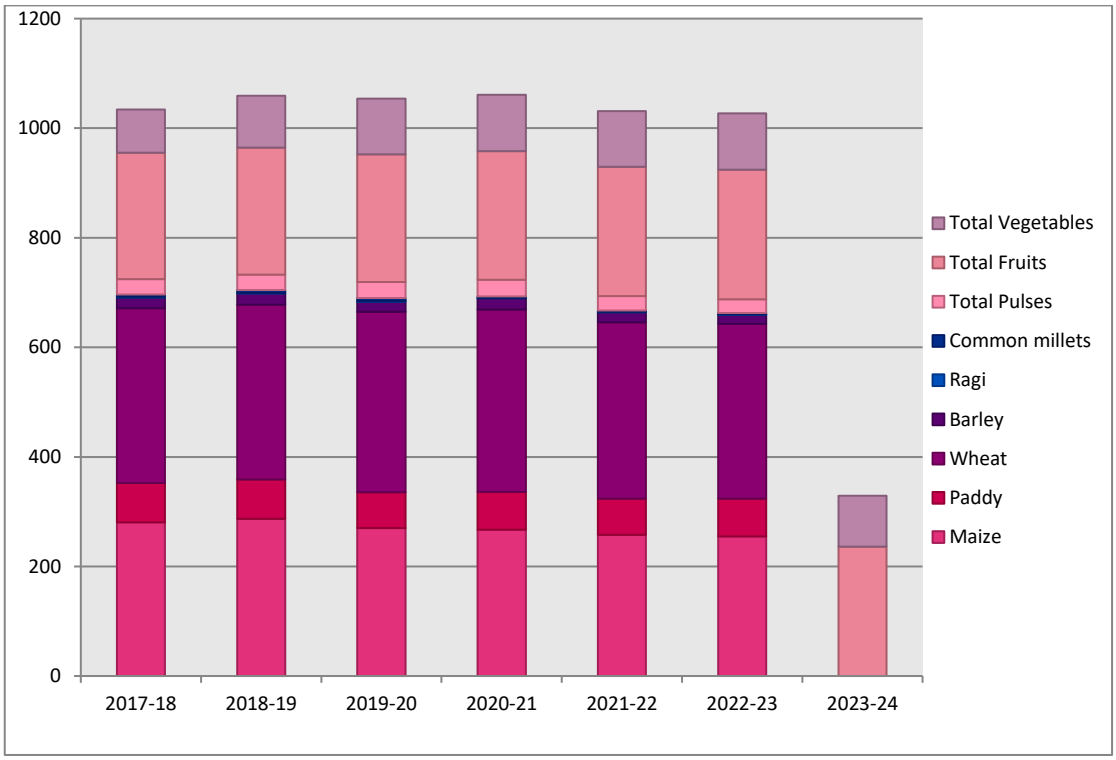


Figure 3. Area under cultivation for different crops in Himachal Pradesh from 2017-2018 to 2023-2024.

Wheat is relatively stable, but maize, barley, and millets show steady decreases, indicating a contraction of cereal cultivation. On the other hand, fruits and vegetables exhibit consistent growth, with vegetables in particular showing a

significant increase from 78.68 to 102.59 thousand ha. The data thus provides a clear statistical basis for identifying the ongoing shift from cereals to horticulture.

Figure 3 clearly depicts the gradual decline in the area under cereals and pulses between 2017–18 and 2022–23, with wheat remaining stable but maize and minor cereals showing a steady decrease. In contrast, fruits and vegetables display a consistent increase, highlighting the ongoing shift towards high-value horticultural crops. For 2023–24, only data for fruits and vegetables were available, and the bar therefore represents these two categories alone. The figure overall reflects the process of crop diversification in Himachal Pradesh, where farmers are moving away from traditional food grains towards fruits and vegetables.

Table 2. Production (in 000′ Metric tons)

S. No	Crop	Year						
		2017-18	**2018-19**	**2019-20**	**2020-21**	**2021-22**	**2022-23**	**2023-24**
1	Maize	750.91	725.553	679.502	715.096	690.975	683.118	742
2	Paddy	141.37	114.896	128.683	136.263	149.543	131.498	199
3	Wheat	598.32	564.634	648.213	573.870	647.274	612.324	620
4	Barley	28.19	36.030	26.893	27.173	29.735	25.289	30
5	Ragi	1.92	1.823	2.06	0.49	1.06	0.305	1.07
6	Common millets	3.36	4.060	4.77	2.12	1.41	4.014	3.26
7	**Total cereals**	**1524.07**	**1446.996**	**1490.121**	**1455.012**	**1519.997**	**1456.548**	**1595.33**
8	Total pulses	56.99	54.000	40.903	50.23	38.057	35.239	56
9	**Total food grains**	**1581.06**	**1500.996**	**1531.024**	**1505.242**	**1558.054**	**1491.787**	**1651.33**
10	Total fruits	565.307	495.362	845.422	624.485	753.977	814.601	721.98
11	Total vegetables	1890.22	1746.998	2057.380	2063.71	2098.986	2061.913	2044.896
12	**Total food crops**	**4036.587**	**2423.796**	**2753.826**	**4193.437**	**4411.017**	**4368.301**	**4418.206**

Source: (i) Himachal Pradesh government annual season and crop report for year 2017-2023, Directorate of land records H.P.
(ii) Statistical abstract of Himachal Pradesh 2017-18.
(iii) Department of agriculture Himachal Pradesh.
(iv) Statistical year book Himachal Pradesh 2022-23, Department of economic & statistics, Himachal Pradesh, Shimla.
(v) Statistical abstract of Himachal Pradesh 2023-24: Data visualization.

The table 2 highlights trends in crop production (in 000’ metric tons) in Himachal Pradesh from 2017-18 to 2023-2024, showing fluctuations across cereals, pulses, food grains, fruits and vegetables. These variations may be influenced by weather conditions, farming techniques, or shifts in market demand.

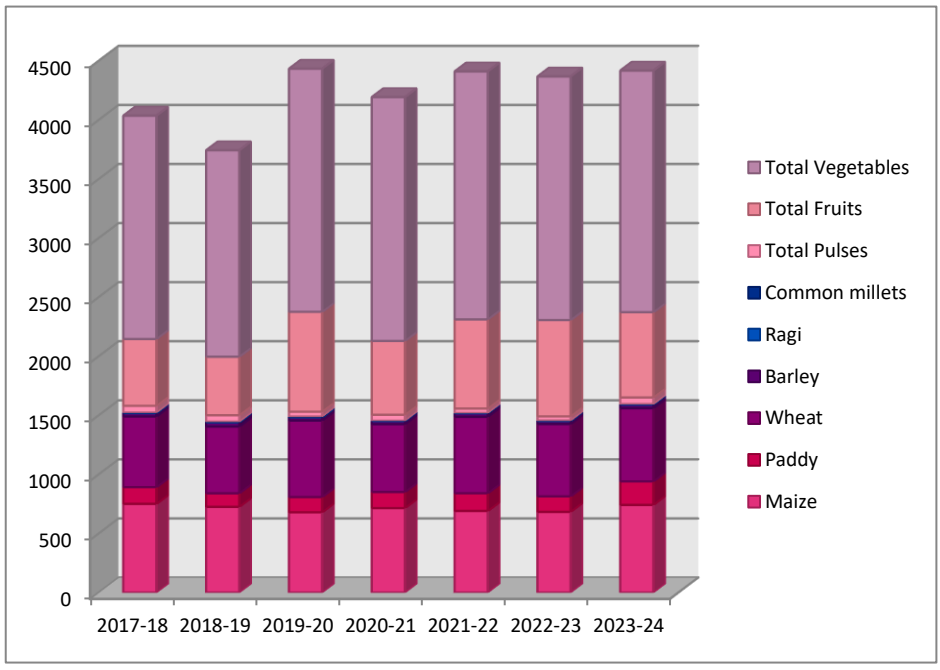


Figure 4. Stacked bar chart of crop production over the years (in 000’ metric tons) from 2017-2018 to 2023-2024

Maize production initially declined from 750.91 thousand tons in 2017-18 to 679.50 thousand tons in 2019-20 but later recovered slightly in 2020-2021 (715.10 thousand metric tons.). After another dip in 2021-2022 (690.97thousand metric tons), it rebounded to 742 thousand metric tons in 2023-24. Before peaking at 199 thousand metric tons in 2023-24, the paddy production was initially low (114.896) in 2018-19. The production of wheat is fairly stable ranging from 598.32 thousand tons (2017-18) to 620 thousand tons (2023-24). Among other cereals, barley fluctuated between 26.89and 36.03 thousand metric tons, while Ragi saw a sharp decline (0.305 thousand tons in 2022-23) before a minor recovery. Common millets displayed erratic trends, with production dropping notably in 2021-22 before improving. Total cereal and food grain production remained relatively stable around 1500 thousand metric tons. Total food crop production dipped in 2018-19 (2423.796 thousand metric tons) but saw an increase in 2020-21 (4193.437 thousand metric tons), likely due to favorable policies or climatic conditions. Similarly in 2023-24 figures (4418.21 thousand metric tons) remained well above earlier levels, indicating a sustained shift in agricultural outputs. These trends provide valuable insights for policymakers and farmers in optimizing crop strategies and ensuring farming practices. Vegetables (light green) dominate, occupy largest portion of total production in most years. Fruit production remains relatively stable across the year but show an increase in 2019-20(845.422 thousand metric tons) and 2022-23(814.601 thousand metric tons) as compared to previous years possibly driven by favourable climatic conditions and improved government policies. A slight decline is observed in 2023-2024(721.98 thousand metric tons), but it remains an important contributor. This indicates the possibility of development in technology or better agricultural methods. Cereal (maize (blue), wheat (dark green), paddy (red)) maintain a significant share. The contribution of total pulses, Ragi, barley, and common millets is relatively small compared to other crops, hence there is some fluctuation in their production, but they remain a minor component. Although, minor grains like barley, millets and ragi made up small portion of total production, it shows that traditional diversity still exists within the system. The highest total production is observed in 2022-23 and 2023-24, mainly due to a rise in vegetable and fruit production. A significant dip is noticeable in 2018-2019, where the overall crop production was lower than in other years.

Facilitating factors of crop diversification

Diversification is a key component of an economy's structural development. Agriculture in Himachal Pradesh has become more diverse in terms of crop, Vegetables and horticultural production. Crop diversification in Himachal has four main goals: first, to boost small-scale household incomes; second, to provide broader employment in farm households; third, to stabilize farm revenue over the seasons; and fourth, to preserve and improve natural resources Latta et al., (2017).

1. Climate change: Agriculture is primary source of revenue and the backbone of countries that are still developing, employing about 55% of the labor force and 67% of population in agriculture and related businesses**.** Climate change, which is currently a major issue all around the world, is expected to have the greatest impact on agriculture because weather plays a critical role in agricultural productivity and yield (Singh et al., 2024). Because of more unfavorable and unpredictable weather patterns brought on by climate change, there is shifting in crop production areas and decline in crop yield also the crops become susceptible to pests and diseases. Therefore, crop diversification through increased usage of minor and underutilized crops is regarded as a crucial strategy to lessen the consequences of climate change on agriculture (Mustafa et al., 2019). At lower elevations, these climate changes are having a detrimental effect on the production of basic crops like rice, wheat, maize but at higher elevations they might present chances to take advantage of Climate Change Driven Agricultural Frontiers (Kc et al., 2022). As microclimates grow more conductive to agriculture, farmers have started growing crops at higher elevations. Reduced snowfall, longer droughts and rising temperatures have rendered many regions unsuitable for apple cultivation due to which apple farming has decreased in lower parts of Kullu and Mandi districts, prompting farmers to shift towards crops such as tomatoes and peas. Consequently, apple cultivation has shifted to higher elevation regions (Jangra & Sharma, 2013). Himachal Pradesh is experiencing a significant adverse effect on habitat health, water and food safety and agricultural output due to changes in climate such as rising temperature, melting glaciers and more frequent droughts and floods. Sharma & Chauhan, (2013) conducted a study in Spiti sub -division of Lahaul-Spiti district of Himachal Pradesh and concluded that the prevalence of suitable microclimate niches for the production of high value cash crops, or off-season vegetable crops such as potatoes and green peas, led to the shift in cropping patterns. The state's farming sector is heavily impacted by the negative consequences of abnormal climatic conditions such as drought and unpredictable, infrequent rainfall. It is always dangerous to solely rely on one or two major cereals (rice, wheat, etc.) in these unusual weather conditions. Therefore, in order to mitigate the issues brought on by unusual weather and to maintain their standard of living, farmers have diversified their farms by substituting one crop or by using mixed cropping or intercropping (Rana et al., 2015).

2. Institutional support: In order to promote crop diversification in Himachal Pradesh, a network of research and development (R&D) organizations are established by central government such as Central Potato Research Institute at Shimla, National Institute of Mushroom Research at Solan, IARI Regional Research Station for vegetable Research at

Katrain (Kullu) and Institute of Himalayan Bio-resources Technology at Palampur. A distinct university of Horticulture and Forestry was established in addition to Agricultural University to provide technical and extended support for the expanding horticulture industry. With the assistance from World Bank, the Himachal Produce Marketing and Processing Corporation (HPMC) was established in 1971 with the goal of supplying vital post-harvest infrastructure, such as link roads, cold storage and facilities for grading and packing. Through the development of appropriate technologies and the provision of advice to farmers regarding varieties appropriate for the agro-climatic conditions of their respective regions, their agronomic practices and crop protection strategies, these research institutions gave the much needed support to cultivation of high-value cash crops. Therefore, the process of crop diversification was accelerated by the easily accessible technological expertise in these government horticulture and agriculture departments and its dissemination to rural communities via their network of regional research stations (Sharma, 2011).

3. Farm revenue: As concerns about food security and income have grown, farmers have started producing more improved and new cash crop varieties in an effort to increase farm revenue (Rana et al., 2015). The possibility for creating jobs and revenue varies throughout various crop businesses. For marginal and small farmers as well as other groups, vegetable crops offer profitable employment despite their labor-intensive nature (Kumar et al., 2016). Growing commercial crops like off-season fruits and vegetables-especially apples instead of traditional cereal crops enable the farmers of state to earn much more money and enjoy much better living conditions (Singh et al., 2004). Prices for fruits and vegetables have steadily grown. Given the strong income elasticity of fruits and vegetables, desire for these commodities will remain insistent, resulting in substantially higher prices. As a result of rising prices, the area devoted to high value crops has expanded which further raise horticultural profitability and productivity (Kumar et al., 2011). Diversifying crop businesses and off-farm revenue and job prospects are the most crucial tactics used by rural farmers to mitigate crop risk and maintain their financial status and expenditure. In order to lower total risk, prudent farm households are diversifying their sectoral revenue (Girish & Mehta, 2003).The expansion of protected cultivation technology in the state has been greatly aided by the technological contributions of two SAUs and their twelve KVKs working with line departments due to which hill farmers have a better standard of living owing to increased production of vegetables and other high-value cash crops ultimately, promoting crop diversification (Choudhary, 2016). In the very beginning phases of development, farmers tended to grow basic food grain crops. As the population grew, they attempted to increase production to maximize farm output. Lastly, crop diversification was implemented to further reinforce the current level of development (Kumar, 2016).

4. Supply and Demand: High value crops have the potential to be a new source of growth when considering supply and demand aspects. The consumer demand for fruits and vegetables grow stronger as the economy opened up and per capita income increased. Due to rise in per capita income, consumers are leaning more towards foods like vegetables and fruits (Jha et al., 2009).

5. Crop diversification projects/Schemes/Programs: The agro climatic conditions in Himachal Pradesh are ideal for horticulture which includes growing fruits and vegetables particularly off-season vegetables. The state government has implemented a number of incentive programs, schemes and projects to support horticultural development in state (Singh et al., 2004). One of those projects is Himachal Pradesh Crop Diversification Promotion Project (HPCDP). In 2011, Phase-I of the Himachal Pradesh Crop Diversification Promotion Project was carried out in five districts of the state- Bilaspur, Hamirpur, Una, Kangra and Mandi- by Himachal Pradesh government in partnership with the Japan International Cooperation Agency- Official Development Assistance (JICA-ODA) for the duration of 2011-2018. Before the execution of project, majority of area was under cereals and cereal production predominated during both kharif and rabi seasons however, a significant increase in both area as well as yield of vegetable and fruit crops was noted following the project's execution, suggesting that crop diversification occurred as the area under farming shifted from cereal based cropping system to vegetable and fruit crop based cropping system (Sarial et al., 2020).The phase-II of Himachal Pradesh Crop Diversification Project, which was signed in March 2021, is currently being implemented in all 12 districts of state and since project area encompasses all 12 districts, it is anticipated that HPCDP phase-II will benefit more farmers. A program called the Mission for Integrated Development of Horticulture (MIDH) program includes, Horticulture Mission for North East and Himalayan states (HMNEH) which is being carried out to promote overall improvement of Horticulture in North East and Himalayan states. The mission covers each aspect of horticulture from production of goods to their consumption. The government of Himachal Pradesh with the financial support from Asian Development Bank (ADB) has implemented the Himachal Pradesh Subtropical Horticulture, Irrigation and Value Addition (HPSHIVA) project to enhance fruit production in sub-tropical regions of the state. The project is being implemented in seven districts of Himachal Pradesh i.e. Bilaspur, Hamirpur, Mandi, Kangra, Solan, Sirmour and Una. This project seeks to increase horticulture by creating infrastructure, encouraging drip irrigation and high-density farming for 25,000 farmers and enhancing market accessibility. Through infrastructure construction and training, the initiative seeks to improve farmer marketing groups, safeguard crops, eliminate income disparities and establish sustainable livelihoods. These initiatives promote crop diversification from cereals to fruits and off-season vegetables in

state. The Himachal Pradesh government has also introduced the kisan Bagwaan Samridhi Yojana (Agriculture Department) for cash crops or precision farming and the Horticulture Development Project (Horticulture Department) which offers SC/ST/BPLs 50% of the subsidy for planting orchards, while small farmers receive 25% and marginal farmers receive 33.3% of subsidy (Negi, 2024).Other than the above mentioned schemes/projects/programs, the state or centre government also introduced Quality Seed Multiplication and Distribution, Development of Seed Potato, Rashtriya Krishi Bima Yojna (RKBY), Paramparagat Krishi Vikas Yojana, Vegetable Development Project and Mukhyamantri krishi samvardhan Yojana (MKSY) (Negi, 2024; Singh et al., 2004) and various other schemes/programs that promoted crop diversification.

6. Other factors: Devi & Prasher, (2019) in their study showed that net irrigated area, average household income, average land holding size, family labor involved in agriculture, educational background of family and experience and training in farming, the ratio of gross irrigated land to total cropped area and regulated agricultural markets all play a significant role in encouraging crop diversity. In their research, they observed that for all crops, a rise in irrigated area causes the diversification index value to decrease, signifying a rise in agricultural diversification. Sharma, (2018) conducted a study on crop diversification in Mandi district of Himachal Pradesh. The findings demonstrated that crop diversity on both small and large farms in the research area was significantly positively impacted by the amount of operating holdings. This implies that bigger the farm size, more diverse is the cropping pattern. Age and education also had a considerable beneficial effect on crop diversity while household size had both positive and negative impact. The labor-intensive industry of vegetable cultivation can give rural residents good-paying jobs. It emphasizes how vegetable cultivation may help individuals in rural regions find employment and financially support themselves (Barwal & Sharma, 2023). According to a study conducted by Girish & Mehta, (2003) in Kangra district of Himachal Pradesh, the number of disintegrated agricultural landholdings had a favorable impact on crop diversification since it made it possible to cultivate a greater range of crops. Furthermore, farm that were more distant from towns showed more diversity and farms that were close to metalled highways showed more crop diversification, possibly as a result of better access to markets and transportation. The state government has provided grading, packaging, manufacturing, transportation and financial services to promote horticulture in Himachal (Singh et al., 2004).

Constraints in crop diversification

The main obstacles to crop diversification are excessive and inappropriate use of resources, such as land and water which have a detrimental effect on sustainability. Modernization and automation are constrained by land fragmentation and diversification is further hampered by inadequate infrastructure (roads, power, transportation and communication). The problems are exacerbated by a lack of post-harvest technologies, an inadequate supply of high-quality seeds and plants and a weak agro-based economy. Diversification is also hampered by shortage of educated human resources, recurrent pest and disease outbreaks, poor research-extension-farmer links and low literacy rates among farmers (Lakhran et al., 2017). According to Kumar et al., 2024, electricity, cropping intensity, agricultural credit and availability of fertilizers are also some of the factors that affect crop diversification. The issue is made worse by inadequate databases on horticultural crops and decline in agricultural investments (Lakhran et al., 2017). Devi et al., 2020 conducted a study in Una (Zone-I), Solan (Zone-II), Shimla (Zone-III) and Kinnaur (Zone-IV) districts of Himachal Pradesh and reported that lack of irrigation facilities was the major constraint in production of different crops in Zone-I, II & II. Deforestation, grazing and forest intrusion brought on by growing human population have severely impacted wildlife habitat. As a result of these activities, some wild animals have adapted to the human altered surroundings due to which farmers are facing a significant problem of crop damage by stray and feral animals especially monkeys (Devi et al., 2020). Among many issues, the horticultural industry in Himachal Pradesh suffers a number of difficulties such as low-quality planting materials, poorly designed orchards, shortage of pollinizers, insufficient tree training and pruning and inadequate plant nutrition. Additionally, inadequate post-harvest quality control, inappropriate orchard management and lack of plant protection material all contribute to significant damage and wastage. With only 4% of fruits and vegetables being processed in state at the moment, the sector is further hampered by lack of preliminary cooling and cold storage as well as inadequate processing facilities (Singh et al., 2004). Therefore, farmers find crop diversification process risky and less lucrative due to these constraints.

Impacts of crop diversification

Increase in household income: The state's average farm income is Rs.1,05,770 per year with zone-II earning Rs.87,469 and zone-IV earning Rs.1,61,037. Field crops account for 34% of revenue, vegetables for 32% and animals for 35%. Field crops and cattle provide for 90% of income in Zone-I, whilst vegetables account for the largest portion (42-45%) in Zones II and III. Vegetable crops account for 85% of farm income in Zone-IV (Sarial, 2019).

Soil Health: Soil health is defined as the ability of a living soil to support plant and animal productivity, preserve or improve water and air quality and support plant and animal health within the confines of a natural or managed ecosystem (Zhang et al., 2020). The key to maintaining soil health is crop diversification through residue assimilation. While the quantity and quality of organic matter vary depending on the crops cultivated in a field, diverse cropping systems are one of the most important options that can help the soil by providing it with organic matter (Kumar et al., 2021). According to a study conducted by (Baldwin-kordick et al., 2022) the greatest effects on earthworm and microbial populations were seen when cropping systems were diversified, suggesting that these biotas had better soil habitat. According to Li et al., (2024), crop diversification considerably raised the bulk soil carbon by 3.3%, in comparison to monoculture. In addition, the percentage of micro aggregates and the carbon content that they were associated with increased significantly by 5% and 12.5%, whereas the percentage of micro aggregates and their corresponding carbon content decreased significantly as a result of crop diversification. Their results show that in the agriculture systems all around the world, crop diversification increases soil organic carbon (SOC) levels and encourages soil aggregation, hence promoting soil health. Kumari et al., (2024) contrasted different cropping systems in terms of crop productivity and profitability, nutrient loss and soil health. The results of monocropping systems revealed significant soil nutrient loss from water and soil erosion, whereas cropping systems with a variety of crops decreased erosion and nutrient loss and increased crop profitability and production. Additionally, by increasing the availability of N and P, systems with a variety of crops and better soil cover throughout the season enhanced soil health.

Disease and insect pest control: Farmers generally rely on pesticides to manage pests, diseases and weeds, preventing production losses and degradation in agricultural product quality. Excessive pesticide use has negatively impacted agro ecosystem activities, leading to a loss in essential ecological functions like biological regulation of pests and pollination. Therefore, reducing pesticide use is a crucial step towards sustainable agricultural systems that use non-chemical pest management technique (Nandillon et al., 2024). Arthropod Pests are majorly responsible for crop damage and yield loss. Pest populations can be directly controlled by crop diversification over time and space through three primary collaborative effects: (i) changing how arthropod pests identify and choose the primary host crop plant ;(ii) increasing crop resistance or tolerance to pests and (iii) disrupting resource spatiotemporal continuity. Additionally, diversity in crops helps to improve crop defenses against insect infestations (Jaworski et al., 2023).

Food and nutritional security: Crop diversification can promote nutritional and food security by optimizing land and water resources, promoting sustainable agricultural growth, creating job opportunities, increasing income and reducing poverty (Jasrotia et al., 2023).

Climate resilience: Increased occurrences of adverse weather occurrences and modified growth conditions pose a threat to crop yields. Because diversification distributes risk among several crop varieties that are adapted to various environments, it can improve resilience to climatic unpredictability (Mihrete & Mihretu, 2025). Numerous other studies have also shown that in order to adjust to the effects of climate change on rain fed crops, farmers are gradually shifting to high-value cash crops particularly irrigated horticulture. Technological developments like improvements in irrigation and market accessibility facilitate these adjustments. However, as future climatic conditions may limit these chances, reliance on crops that require more water could compromise farmer's long-term adaptive potentiality (Labeyrie et al., 2021).

Others: Various other impacts include market price variability, improved nutritional security support for biodiversity conservation, enhanced pollination services and reduced soil degradation.

Conclusion

Shift towards Horticulture: Himachal Pradesh's diverse agro-climatic conditions have resulted in the prevalence of ideal microclimate niches for the development of high value cash crops, as well as off-season vegetable crops such as potatoes and green peas. There is a visible increase in the area under fruits and vegetables, highlighting a diversification from traditional cereals to high-value crops. **Declining Cereal Cultivation:** The slight decline in wheat, maize, and barley indicates a gradual reduction in food grain production. This suggests that weather, policies, or market conditions influenced agricultural land use. Vegetables and fruits play a crucial role in total production, with vegetables showing the most variation over the years. A sharp decline in total production occurred in 2018-19 and 2023-24 saw the highest production levels. Pulses and minor cereals contribute the least but maintain a steady presence. This diversification from cereals to high value commodities can improve soil health, helps to control pest population and the diseases caused by them. Crop diversification can also promote food and nutritional security by optimizing the use of land and water resources and also improve resilience to climatic unpredictability. The analysis of factors that facilitated the process of crop diversification indicated that prevalence of microclimates due to climate change, increase in farm revenue and

household income, high demand and preference for horticultural crops are the major factors. The net irrigated area, average household income, average land holding size, family labor involved in agriculture, educational background of family and experience and training in farming, the ratio of gross irrigated land to total cropped area and regulated agricultural markets, better access to markets and transportation all play a significant role in encouraging crop diversity. In addition to this various government institutions like Central Potato Research Institute at Shimla, National Institute of Mushroom Research at Solan, IARI Regional Research Station for vegetable Research at Katrain (Kullu), Institute of Himalayan Bio-resources Technology at Palampur, University of Horticulture and Forestry and Agriculture University extend support for expanding horticulture industry. These factors facilitated the process of crop diversification even in tribal regions like Lahaul and Spiti, Kinnaur etc. Crop diversification is still in progress but it is constrained by many factors like excessive and inappropriate use of natural resources, activities like deforestation, overgrazing and forest intrusion which harm ecosystem and encourage crop damage by stray/feral animals especially monkeys. Lack of easy excess to roads, markets, poor irrigation facilities, shortage of post-harvest technologies and storage facilities limits the production of horticultural produce. Other factors like poor linkage between research institutions, extension services and farmers, inadequate supply of quality seeds as well as planting material also hinders the process of crop diversification. However, these limitations can be overcome by (i) implementing programs to enhance efficient irrigation through rainwater harvesting and integrated watershed management. (ii) Encouraging precision farming practices. (iii) Providing post-harvest storage and processing units. (iv) Taking appropriate initiatives for starting farmer education and skill building programs. (v) Provide easy credit access for quality seeds, planting materials, fertilizers and plant protection materials. (vi) Strengthen the horticultural databases and increase investments in agriculture.

Author contributions

Conceptualization, data collection and data curation, software, writing original draft; Sharma S.; review and editing; Sharma P.; review, editing and supervision; Upmanyu S. All authors have agreed to the final version of manuscript.

Acknowledgment

NIL.

Funding

No funding

Conflict of interest

The authors declare no conflict of interest. The manuscript has not been submitted for publication in other journal.

Ethics approval

Not applicable.

AI tool usage declaration

The authors not used any AI and related tools to write this manuscript.

References

Baldwin-Kordick, R., De, M., Lopez, M. D., Liebman, M., Lauter, N., Marino, J., & McDaniel, M. D. (2022). Comprehensive impacts of diversified cropping on soil health and sustainability. *Agroecology and Sustainable Food Systems*, *46*(3), 331-363. https://doi.org/10.1080/21683565.2021.2019167

Barwal, P., & Sharma, S. (2023). Cost and Return Structure of Vegetables in Different Agro-climatic Zones of Himachal Pradesh. https://doi.org/10.35716/IJED-22417

Chaudhary, J., & Singh, H. P. (2020). Diversification of agricultural crops in Himachal Pradesh: a shift towards high-value crops. *Int J Curr Microbiol Appl Sci*, *9*(12), 2224-2235. https://doi.org/10.20546/ijcmas.2020.912.262

Latta, A., Chaudhary, K., Attri, A., (2017). Agriculture development in Himachal Pradesh: An Empirical Study. *International Journal of Research*, 4(9).

Choudhary, A. K. (2016). Scaling-up of protected cultivation in Himachal Pradesh, India. *Current Science*, 272-277. https://www.jstor.org/stable/24908614

Devi, N., & Prasher, R. S. (2019). Growth and Diversification of Mountain Agriculture: A Case Study of Himachal Pradesh. *Economic Affairs*, *64*(1), 47-53. http://dx.doi.org/10.30954/0424-2513.1.2019.7

Devi, N., Raina, K. K., & Sharma, R. (2020). Constraints faced by the farmers of Himachal Pradesh in production of different crops. *Bulletin of Environment, Pharmacology and Life Sciences*, *9*(4), 13-18.

Gangwar, B., & Singh, A. K. (2011). *Efficient alternative cropping systems*. Project Directorate for farming system Research.

Girish, M., & Mehta, P. (2003). Crop diversification: An empirical analysis on Kangra farms of Himachal Pradesh, India. *Asia-Pacific Journal of Rural Development*, *13*(2), 1-18. https://doi.org/10.1177/1018529120030201

Gummagolmath, K. C., Bhawar, R. S., Lakshmi, S. R., & Patra, P. (2020). Impact of crop diversification on farmers socio-economic conditions of the farmers: A case of Himachal Pradesh. *Research Journal of Agricultural Sciences*, *11*(1), 137-143.

Lakhran, H., Kumar, S., & Bajiya, R. O. H. I. T. A. S. H. (2017). Crop diversification: an option for climate change resilience. *Trends Biosci*, *10*(2), 516-518.

Jangra, M. S., & Sharma, J. P. (2013). Climate resilient and apple production in Kullu valley of Himachal Pradesh. *International Journal of Farm Sciences*, *3*(1), 90-97.

Jasrotia, P., Kumari, P., Malik, K., Kashyap, P. L., Kumar, S., Bhardwaj, A. K., & Singh, G. P. (2023). Conservation agriculture-based crop management practices impact diversity and population dynamics of the insect-pests and their natural enemies in agroecosystems. *Frontiers in Sustainable Food Systems*, *7*, 1173048. https://doi.org/10.3389/fsufs.2023.1173048

Jaworski, C. C., Thomine, E., Rusch, A., Lavoir, A. V., Wang, S., & Desneux, N. (2023). Crop diversification to promote arthropod pest management: A review. *Agriculture Communications*, *1*(1), 100004. https://doi.org/10.1016/j.agrcom.2023.100004

Jha, B., Tripathi, A., & Mohanty, B. (2009). Drivers of Agricultural Diversification in India, Haryana and the Greenbelt Farms of India.

Kc, K. B., Tzadok, E., & Pant, L. (2022). Himalayan ecosystem services and climate change driven agricultural frontiers: a scoping review. *Discover sustainability*, *3*(1), 35. https://doi.org/10.1007/s43621-022-00103-9

Kumar, A. (2016). Impact of Watershed Development Programme on Crop Diversification: A Study of Himachal Pradesh. *Hill Quest (A National Multidisciplinary Refereed online Journal)*, *3*(3-4), 47-68. http://www.hillquest.pratibha-spandan.org/

Kumar, A., Dogra, A., & Guleria, J. S. (2016). Sustainable Production Systems for Agriculture Development in Mountains of Himachal Pradesh, India. *Asian Journal of Agricultural Extension, Economics & Sociology*, *14*(1), 1-9. 10.9734/AJAEES/2016/29033

Kumar, C. R., Nayak, C., & Pradhan, A. K. (2024). Status and determinants of crop diversification: evidence from Indian States. *Letters in Spatial and Resource Sciences*, *17*(1), 1. https://doi.org/10.1007/s12076-023-00366-4

Kumar, M., Mitra, S., Mazumdar, S. P., Majumdar, B., Saha, A. R., Singh, S. R., ... & Hossain, A. (2021). Improvement of soil health and system productivity through crop diversification and residue incorporation under jute-based different cropping systems. *Agronomy*, *11*(8), 1622. https://doi.org/10.3390/agronomy11081622

Kumar, P., Kumar, A., Shinoj, P., & Raju, S. S. (2011). Estimation of demand elasticity for food commodities in India §. *Agricultural Economics Research Review*, *24*(1), 1-14.

Kumar, S. (2017). Economics of Crop Cultivation in Himachal Pradesh: Facts from Cost of Cultivation Data. *Indian Journal of Economics and Development*, *13*(2), 295-304. http://dx.doi.org/10.5958/2322-0430.2017.00179.2

Kumari, V. V., Balloli, S. S., Kumar, M., Ramana, D. B. V., Prabhakar, M., Osman, M., ... & Timsina, J. (2024). Diversified cropping systems for reducing soil erosion and nutrient loss and for increasing crop productivity and profitability in rainfed environments. *Agricultural Systems*, *217*, 103919. https://doi.org/10.1016/j.agsy.2024.103919

Labeyrie, V., Renard, D., Aumeeruddy-Thomas, Y., Benyei, P., Caillon, S., Calvet-Mir, L., ... & Reyes-García, V. (2021). The role of crop diversity in climate change adaptation: Insights from local observations to inform decision making in agriculture. *Current Opinion in Environmental Sustainability*, *51*, 15-23. https://doi.org/10.1016/j.cosust.2021.01.006

Li, G., Yu, C., Shen, P., Hou, Y., Ren, Z., Li, N., ... & Wen, X. (2024). Crop diversification promotes soil aggregation and carbon accumulation in global agroecosystems: A meta-analysis. *Journal of Environmental Management*, *350*, 119661. https://doi.org/10.1016/j.jenvman.2023.119661

Mihrete, T. B., & Mihretu, F. B. (2025). Crop Diversification for Ensuring Sustainable Agriculture, Risk Management and Food Security. *Global Challenges*, 2400267. https://doi.org/10.1002/gch2.202400267

Mustafa, M. A., Mayes, S., & Massawe, F. (2019). Crop diversification through a wider use of underutilised crops: A strategy to ensure food and nutrition security in the face of climate change. In *Sustainable solutions for food security: combating climate change by adaptation* (pp. 125-149). Cham: Springer International Publishing.

Nandillon, R., Guinet, M., & Munier-Jolain, N. (2024). Crop management strategy redesign enables a reduction in reliance on pesticides: A diachronic approach based on a diversity of French commercial farms. *Agriculture, Ecosystems & Environment*, *366*, 108949. https://doi.org/10.1016/j.agee.2024.108949

Negi, G. C. S. (2024). Rural development schemes in the Indian Himalayan region: Prospects and challenges. *Kashmir Journal of Social Sciences, 12*(1), 96–117.

Rana, S. S., Sharma, S. K., Negi, S. C., Soni, R. P., & Katoch, M. (2015). An exploratory study on farm diversification in Himachal Pradesh. *Himachal Journal of Agricultural Research*, 66-72.

Reddy, A. A. (2009). Pulses production technology: Status and way forward. *Economic and Political weekly*, 73-80. https://www.jstor.org/stable/25663942

Sarial, A. K. (2019). Challenges and opportunities in crop diversification. *Himachal Journal of Agricultural Research*, 1-14.

Sarial, A. K., Sharma, K. D., Kumar, V., Rana, J. C., Sharma, V. K., & Nath, V. (2020). Impact of Himachal Pradesh and Japan International Cooperation Agency Crop Diversification Promotion Project on farmers' income and food security-An appraisal. *Himachal Journal of Agricultural Research*, 1-12.

Sharma, H. R. (2005). Agricultural development and crop diversification in Himachal Pradesh: understanding the patterns, processes, determinants and lessons. *Indian Journal of Agricultural Economics*, *60*(1).

Sharma, H. R. (2011). Crop diversification in Himachal Pradesh: Patterns, determinants and challenges. *Indian Journal of Agricultural Economics*, *66*(1).

Sharma, H. R., & Chauhan, S. K. (2013). Agricultural transformation in Trans Himalayan region of Himachal Pradesh: cropping pattern, technology adoption and emerging challenges. *Agricultural Economics Research Review*, *26*, 173-179. http://dx.doi.org/10.22004/ag.econ.158503

Sharma, M. (2018). *Study on crop diversification in mandi district of himachal pradesh* (Doctoral dissertation, CSKHPKV, Palampur).

Singh, A., Arora, K., & Chandra Babu, S. (2024). Examining the impact of climate change on cereal production in India: Empirical evidence from ARDL modelling approach. *Heliyon*, *10*(18), e36403. https://doi.org/10.1016/j.heliyon.2024.e36403

Singh, P., Guleria, A., Vaidya, M. K., & Sharma, S. (2020). Determinants of diversification in relation to farm size and other socio-economic characteristics for sustainable hill farming in Himachal Pradesh. *Indian Journal of Economics and Development*, *16*(3), 418-424. http://dx.doi.org/10.35716/IJED/20064

Singh, R. B., & Kumar, P. (2014). Geographic and socio-economic realities of Himachal Pradesh, Northwestern Himalaya. *Livelihood Security in Northwestern Himalaya: Case Studies from Changing Socio-economic Environments in Himachal Pradesh, India*, 11-26.

Singh, R., Saraswat, S. P., & Singh, P. (2004). *Agricultural Policy in Himachal Pradesh: A Policy Matrix in a Federal System*. Agro-Economic Research Centre, Himachal Pradesh University.

Singh, S., & Kumar, M. D. (2022). Land utilization and cropping pattern in Himachal Pradesh. *Dogo Rangsang Research Journal, 12*(3), 129-137.

Sood, A., & Kumar, A. (2022). Productivity of cereal crops, pulses and vegetables: household level investigation in *Himachal Pradesh, 8*(7), 11-14.

Zhang, J., Van Der Heijden, M. G., Zhang, F., & Bender, S. F. (2020). Soil biodiversity and crop diversification are vital components of healthy soils and agricultural sustainability. *Frontiers of Agricultural Science and Engineering*, *7*(3), 236. https://doi.org/10.5167/uzh-193808