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Trends in temperate fruit cultivation in the Kumaon Region of Uttarakhand

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Abstract

Temperate fruit cultivation is an important component of the horticultural economy of Uttarakhand, contributing to income generation, employment, and agricultural diversification in the Himalayan region. The present study analysed the trends in area, production, and productivity of major temperate fruits (apple, peach, plum, apricot, and walnut) across five districts of the Kumaon region during 2016-17 to 2020-21 using secondary data. Descriptive statistics, Annual Growth Rate (AGR), Compound Annual Growth Rate (CAGR), and panel data regression techniques were employed. The descriptive analysis revealed considerable spatial variation, with Almora recording the highest average area under walnut (2820.80 ha), plum (2617.20 ha), and apricot (2297.60 ha), while Nainital recorded the highest average peach production (25,895.96 MT) and productivity (141.86 q ha⁻¹). AGR analysis showed a gradual expansion in cultivated area across all crops (0.296-0.748%), while production declined for most crops except walnut, which registered a positive growth rate of 0.477 percent. CAGR analysis demonstrated substantial district-level variability, with the highest area growth observed for peach in Pithoragarh (2.92%) and the highest production growth for walnut in Champawat (6.59%). Both Fixed Effects and Random Effects panel models were estimated, and the Hausman specification test supported the Random Effects model ($\chi^2 = 0.000$; $p = 1.000$). The Random Effects panel regression models explained 22.4%, 22.3%, and 22.8% of the variation in area, production, and productivity, respectively. The findings indicate that although temperate fruit cultivation expanded spatially, productivity constraints limited production gains, highlighting the need for orchard rejuvenation, improved cultivars, climate-resilient technologies, and location-specific extension interventions to ensure sustainable horticultural development in the Kumaon region.

Keywords: Temperate fruits, Kumaon region, AGR, CAGR, Panel data analysis

1. Introduction

Temperate fruit cultivation is an important component of the horticulture sector, contributing to agricultural diversification, nutritional security, rural employment, and farm income, particularly in mountainous regions. High-value fruits such as apple, pear, peach, plum, apricot, and walnut generate greater economic returns per unit area than traditional field crops while creating employment opportunities across production, processing, storage, transportation, and marketing (Bhatt & Sharma, 2019) [3]. In India, the horticulture sector has consistently outperformed the food grain sector in terms of growth over the past three decades, driven by improved planting materials, technological advancements, better crop management, and expanding cultivation (NHB, 2024) [13].

The Indian Himalayan Region provides highly favourable agro-climatic conditions for temperate fruit cultivation (Sati, 2022) [14]. Among the Himalayan states, Uttarakhand is a major producer of temperate fruits owing to its diverse altitudinal range, suitable climate, and rich natural resources (Sati, 2022; Kishor & Kumar, 2022) [14, 11]. Within the state,

the Kumaon region plays a significant role in temperate horticulture (Mehta, 2017; Attri *et al.*, 2015) [12, 1]. However, the performance of temperate fruit cultivation varies considerably across districts due to differences in climatic conditions, orchard age, irrigation facilities, technology adoption, pest and disease incidence, market access, infrastructure, and institutional support (Attri *et al.*, 2015; Sati, 2022) [1, 14].

Previous studies have largely assessed trends in horticultural crops using descriptive statistics and Compound Annual Growth Rate (CAGR). For example, Dharmaraj *et al.* (2026) [5] analysed the performance of horticultural crops under the National Horticulture Mission in Karnataka using descriptive measures and CAGR, while similar studies in Uttarakhand have primarily focused on state-level trend analysis (NHB, 2024) [13]. However, district-level empirical studies examining the temporal dynamics of major temperate fruit crops in the Kumaon region using longitudinal panel data remain limited. Most existing studies do not account for district-specific heterogeneity, reducing the reliability of policy recommendations.

Therefore, the present study examines the temporal trends in area, production, and productivity of major temperate fruit crops in the Kumaon region of Uttarakhand during 2017-2022 using secondary data. The study employs descriptive statistics, Compound Annual Growth Rate (CAGR), and panel data regression techniques to evaluate temporal changes, estimate district-specific effects, and compare the performance of major fruit-growing districts. The findings are expected to provide evidence for policymakers, researchers, and extension agencies in designing location-specific interventions to improve the productivity, profitability, and sustainability of temperate fruit cultivation in Kumaon region of Uttarakhand.

Objectives of the study

1. To analyse the spatio-temporal trends in area, production, and productivity of major temperate fruits across the districts of the Kumaon region of Uttarakhand during 2016-17 to 2020-21.
2. To estimate the Annual Growth Rate (AGR) and Compound Annual Growth Rate (CAGR) of area, production, and productivity of major temperate fruits in the Kumaon region
3. To examine district-specific temporal variations in temperate fruit cultivation using panel data regression models.

2. Materials and Methods

2.1 Study Area

The present study was conducted for the Kumaon region districts of Uttarakhand which consists of six districts out of which five, namely Almora, Bageshwar, Champawat, Nainital, and Pithoragarh were taken excluding Udham Singh Nagar as it is a plain area with zero temperate fruit production. These districts are in the middle and higher Himalayan regions and are characterized by diverse agro-climatic conditions, suitable altitudinal gradients, and temperate climatic conditions that favour the cultivation of apple, pear, peach, plum, apricot, walnut, kiwi, and cherry. Owing to their significant contribution to temperate fruit production, these districts were selected for the present investigation (Government of Uttarakhand, 2024) ^[7].

2.2 Data Source

The study was based entirely on secondary data collected for the period 2017-2022. District-wise annual data on area (ha), production (metric tonnes), and productivity (q ha⁻¹) of major temperate fruit crops were compiled from the Department of Horticulture, Government of Uttarakhand, and official horticultural statistical publications. The use of secondary data for analysing long-term agricultural trends has been widely adopted in horticultural and agricultural economics research (Dharmaraj *et al.*, 2026) ^[5].

2.3 Research Design

The study employed an ex-post facto research design, as the investigation relied exclusively on historical secondary data without manipulating any of the study variables. Ex-post facto designs are widely used in agricultural and social science research for analysing existing datasets to understand temporal changes and trends (Kerlinger & Lee, 2000) ^[10].

2.4 Variables Used

The analysis considered three major indicators of horticultural performance:

- Area under cultivation (ha)
- Production (metric tonnes)
- Productivity (q ha⁻¹)

Productivity was estimated as:

$$\text{Productivity} = \frac{\text{Production (MT)} \times 10}{\text{Area (ha)}}$$

2.5 Statistical Analysis

Descriptive Statistics

Descriptive statistical measure i.e. mean was computed to summarize the characteristics of area, production, and productivity across districts and years (Field, 2018) ^[6].

Annual Growth Rate (AGR)

The year-to-year growth in area, production, and productivity was estimated as:

$$\text{AGR}(\%) = \frac{Y_t - Y_{t-1}}{Y_{t-1}} \times 100$$

where, Y_t is the value in the current year and Y_{t-1} is the corresponding value in the previous year.

Compound Annual Growth Rate (CAGR)

The long-term growth performance of area, production, and productivity was estimated using the Compound Annual Growth Rate (CAGR), which measures the average annual rate of change over a specified period assuming a constant growth rate (Dharmaraj *et al.*, 2026; Gujarati *et al.*, 2018) ^[5]. The CAGR was computed as

$$\text{CAGR} = \left(\frac{Y_n}{Y_0} \right)^{\frac{1}{n}} - 1$$

Where;

- Y_0 = Initial value
- Y_n = Final value
- n = Number of years.

Panel Data Regression Analysis

To examine temporal changes while accounting for district-level heterogeneity, panel data regression models were employed. Panel data analysis combines both cross-sectional and time-series information, thereby improving estimation efficiency and reducing omitted-variable bias compared with conventional regression approaches (Baltagi, 2021; Wooldridge, 2020) ^[2, 15]. The general specification of the model is given by

$$Y_{it} = \beta_0 + \beta_1 \text{Year}_t + \mu_i + \varepsilon_{it}$$

Where;

- Y_{it} represents area, production, or productivity for district i during year t ;

- β_0 is the intercept;
- β_1 denotes the effect of time;
- μ_i captures unobserved district-specific effects; and
- ε_{it} is the random error term.

Separate panel regression models were estimated for area, production, and productivity.

Model Selection

Two econometric specifications were evaluated:

- Fixed Effects Model (FEM)
- Random Effects Model (REM)

The Hausman specification test was employed to determine the most appropriate model. A statistically significant Hausman statistic indicates the preference for the Fixed Effects Model, whereas a non-significant result supports the Random Effects Model (Hausman, 1978; Baltagi, 2021) [9, 2]. Model assumptions were evaluated using diagnostic tests for heteroscedasticity, serial correlation, multicollinearity, and cross-sectional dependence. Robust standard errors were used whenever violations of model assumptions were detected (Wooldridge, 2020) [15].

Data Analysis

Data processing and statistical analyses were performed using R software (Version 4.x). Descriptive analyses were conducted using the tidyverse package, while panel data regression models were estimated using the plm package (Croissant & Millo, 2008) [4].

3. Results and Discussion

3.1 Area, Production and Productivity of Temperate Fruits

The district-wise average area, production, and productivity of major temperate fruits during 2016-17 to 2020-21 are presented in Table 1. Considerable spatial variation was observed among the five districts, reflecting differences in agro-climatic suitability, orchard distribution, varietal composition, and production management practices.

Apple cultivation was predominantly concentrated in Pithoragarh (1617.32 ha) and Almora (1576.40 ha), whereas Bageshwar maintained only a limited cultivated area (98.71 ha). Despite Pithoragarh recording the largest cultivated area, Almora achieved the highest average production (13,629.60 MT) and productivity (86.46 q ha⁻¹), indicating greater production efficiency and better orchard performance. Conversely, Bageshwar registered the lowest production (12.19 MT) and productivity (1.23 q ha⁻¹).

Peach exhibited a distinctly different distribution pattern. Nainital emerged as the leading district with the highest average cultivated area (1825.73 ha), production (25,895.96 MT), and productivity (141.86 q ha⁻¹), followed by Almora. The remarkably high productivity in Nainital highlights its favourable climatic conditions and efficient orchard management for peach cultivation. Comparatively lower productivity in Champawat (18.09 q ha⁻¹) and Bageshwar (21.88 q ha⁻¹) was observed.

Plum cultivation was largely concentrated in Almora, which recorded the highest average area (2617.20 ha) and production (20,323.60 MT). However, Nainital achieved the highest productivity (105.70 q ha⁻¹), demonstrating that

higher production efficiency does not necessarily coincide with the largest cultivated area. Although Pithoragarh maintained the second-largest plum area (945.53 ha), its productivity remained comparatively low (17.32 q ha⁻¹), indicating the influence of factors beyond land allocation, including orchard age, management practices, and varietal performance.

Apricot cultivation also displayed marked district-level variation. Almora dominated in terms of average cultivated area (2297.60 ha), production (17,578.00 MT), and productivity (76.51 q ha⁻¹), followed by Nainital, which recorded comparatively high production (2861.30 MT) and productivity (72.73 q ha⁻¹).

Walnut cultivation was primarily concentrated in Almora and Pithoragarh. Almora recorded the highest average area (2820.80 ha), production (8264.20 MT), and productivity (29.30 q ha⁻¹), whereas Pithoragarh ranked second in both cultivated area (1935.34 ha) and production (1640.80 MT). Nainital exhibited relatively high productivity (25.80 q ha⁻¹) despite having a much smaller cultivated area, while Champawat recorded the lowest productivity (2.25 q ha⁻¹), indicating comparatively poor production efficiency.

The descriptive analysis demonstrates that Almora is the principal temperate fruit-producing district for apple, plum, apricot, and walnut, whereas Nainital possesses a comparative advantage in peach cultivation. These findings underline the heterogeneous nature of temperate fruit production across the Kumaon region, where variations in topography, altitude, climatic conditions, orchard management, and technological adoption collectively influence crop performance.

Table 1: District-wise average area, production and productivity of temperate fruits during 2016-17 to 2020-21

(A) Average Area (ha)

Crop	Almora	Bageshwar	Champawat	Nainital	Pithoragarh
Apple	1576.40	98.71	327.20	1244.84	1617.32
Peach	1665.00	250.04	516.80	1825.73	1106.70
Plum	2617.20	100.32	533.40	588.90	945.53
Apricot	2297.60	81.93	341.00	393.42	781.76
Walnut	2820.80	405.37	272.80	119.93	1935.34

(B) Average Production (MT)

Crop	Almora	Bageshwar	Champawat	Nainital	Pithoragarh
Apple	13629.60	12.19	333.60	7993.14	3037.88
Peach	19945.20	546.94	935.00	25895.96	3800.93
Plum	20323.60	152.66	615.00	6221.16	1638.38
Apricot	17578.00	70.74	373.80	2861.30	1144.05
Walnut	8264.20	967.82	61.60	309.41	1640.80

(C) Average Productivity (q ha⁻¹)

Crop	Almora	Bageshwar	Champawat	Nainital	Pithoragarh
Apple	86.46	1.23	10.20	64.23	18.78
Peach	119.81	21.88	18.09	141.86	34.30
Plum	77.65	15.22	11.53	105.70	17.32
Apricot	76.51	8.63	10.96	72.73	14.64
Walnut	29.30	23.88	2.25	25.80	8.48

3.2 Annual Growth Rate (AGR) of Temperate Fruits

The average annual growth rate (AGR) for area, production, and productivity of major temperate fruits during FY 2017-18 to FY 2020-21 is presented in Table 2. The results indicate

that cultivated area expanded gradually for all selected crops, whereas production and productivity exhibited contrasting trends.

Among the five crops, peach recorded the highest annual increase in cultivated area (0.748%), followed by plum (0.502%) and walnut (0.486%). Apple and apricot showed comparatively modest area expansion, each recording an AGR of 0.296%. The consistent positive growth in cultivated area suggests a gradual increase in farmers' interest in temperate fruit cultivation across the Kumaon region.

In contrast, production growth remained negative for most crops. Apple (-0.222%), peach (-0.051%), plum (-0.005%), and apricot (-0.427%) all recorded declining production growth despite the expansion in cultivated area. This divergence indicates that increases in cultivated area alone were insufficient to sustain production growth, possibly due to climatic variability, ageing orchards, pest incidence, or limitations in orchard management practices. Walnut was the only crop that registered positive growth in both cultivated area (0.486%) and production (0.477%), reflecting comparatively better production performance and adaptation during the study period.

The productivity trends further reinforced these findings. Peach experienced the highest decline in productivity (-0.831%), followed by apricot (-0.721%), apple (-0.525%), and plum (-0.507%). Walnut exhibited only a marginal decline (-0.023%), indicating relatively stable yield performance over time. The simultaneous expansion in cultivated area and decline in productivity for most crops suggests that improvements in orchard management, varietal replacement, nutrient management, and climate-resilient production technologies are essential for sustaining future production.

Table 2: Average Annual Growth Rate (AGR) of Temperate Fruits (2017–18 to 2020–21)

Crop	Area AGR (%)	Production AGR (%)	Productivity AGR (%)
Apple	0.296	-0.222	-0.525
Peach	0.748	-0.051	-0.831
Plum	0.502	-0.005	-0.507
Apricot	0.296	-0.427	-0.721
Walnut	0.486	0.477	-0.023

Note: Average AGR values were computed using district-wise annual growth rates for the period FY 2017–18 to FY 2020–21. The base year (FY 2016–17) was excluded from the calculations.

3.3 Compound Annual Growth Rate (CAGR) of Temperate Fruits

The district-wise compound annual growth rates (CAGR) of area, production, and productivity are presented in Table 3. The cultivated area exhibited positive growth across nearly all district-crop combinations. The most rapid expansion was observed for peach in Pithoragarh (2.92%), followed by walnut in Champawat (2.13%), indicating increasing farmer preference and expansion of these crops in the respective districts. Relatively modest area growth was recorded for apple in Almora (0.10%) and walnut in Nainital (0.04%), suggesting stable rather than expanding cultivation. Production growth displayed substantial variability among districts. Apple production increased markedly in Bageshwar (11.70%), while walnut production showed exceptional

growth in Champawat (6.59%). Peach production in Pithoragarh also increased considerably (4.65%), reflecting favourable production conditions and improved orchard performance. Conversely, apple production declined sharply in Nainital (-15.00%) and Almora (-4.24%), whereas peach and walnut production also decreased substantially in Almora, indicating production instability in these districts.

The productivity CAGR largely mirrored production performance. Bageshwar recorded the highest productivity growth for apple (10.86%), while walnut productivity increased significantly in Champawat (4.37%). However, most district-crop combinations exhibited declining productivity, with the largest reductions observed for apple in Nainital (-15.10%), peach in Almora (-4.18%), and walnut in Almora (-3.67%). These declining productivity trends suggest that expanding orchard area alone was insufficient to enhance yield performance, emphasizing the importance of improved production technologies, orchard rejuvenation, quality planting material, and scientific management practices.

Table 3: Compound Annual Growth Rate (CAGR) of Temperate Fruits (2016–17 to 2020–21)

CAGR (%)	District	Apple	Peach	Plum	Apricot	Walnut
Area	Almora	0.095	0.377	0.019	0.054	0.115
	Bageshwar	0.757	0.679	0.625	0.479	0.491
	Champawat	0.689	0.339	0.375	0.220	2.126
	Nainital	0.116	0.260	1.207	0.109	0.042
	Pithoragarh	0.187	2.918	0.901	0.974	0.255
Production	Almora	-4.243	-3.818	-1.473	-2.263	-3.564
	Bageshwar	11.70	0.183	0.315	1.005	-0.476
	Champawat	1.124	0.536	0.611	0.603	6.592
	Nainital	-14.99	-2.513	-1.352	-2.775	0.004
	Pithoragarh	0.199	4.645	1.763	0.555	0.153
Productivity	Almora	-4.334	-4.179	-1.492	-2.316	-3.675
	Bageshwar	10.86	-0.492	-0.308	0.524	-0.962
	Champawat	0.432	0.196	0.235	0.382	4.373
	Nainital	-15.10	-2.766	-2.529	-2.881	-0.038
	Pithoragarh	0.012	1.678	0.854	-0.416	-0.102

3.4 Panel Data Regression Analysis

Both the Fixed Effects (FE) and Random Effects (RE) panel regression models were initially fitted to analyse the temporal changes in area, production, and productivity of temperate fruits across the districts of the Kumaon region. The appropriate model specification was subsequently determined using the Hausman specification test. The test confirmed that the Random Effects model was the appropriate specification for analysing all three dependent variables, as the null hypothesis of no systematic difference between the Fixed and Random Effects estimators could not be rejected ($\chi^2 = 0.000$; $p = 1.000$). Accordingly, the Random Effects estimator was adopted for the subsequent panel regression analysis.

Table 4: Hausman specification test for panel regression model selection

Dependent variable	χ^2	df	p-value	Selected model
Area	0.000	4	1.000	Random Effects
Production	0.000	4	1.000	Random Effects
Productivity	0.000	4	1.000	Random Effects

The Random effects panel regression results revealed a significant positive temporal trend in cultivated area. Relative to the base year (2016-17), cultivated area increased significantly by 9.36 ha in 2017-18 ($p < 0.01$), 11.88 ha in 2018-19 ($p < 0.001$), 14.06 ha in 2019-20 ($p < 0.001$), and 15.86 ha in 2020-21 ($p < 0.001$). These findings clearly indicate a gradual expansion of temperate fruit cultivation across the Kumaon region during the study period.

None of the crop dummy variables (Apricot, Peach, Plum, and Walnut) were statistically significant relative to the reference crop (Apple), suggesting that after accounting for district-level heterogeneity and temporal variation, differences in cultivated area among the selected fruit crops were not statistically significant. For production, the crop coefficients again remained statistically insignificant, indicating comparable production levels among the fruit crops after controlling for district effects. However, the coefficient for 2020-21 was significantly negative (-629.36

MT; $p < 0.001$), demonstrating a substantial reduction in fruit production during the final year of the study. The positive but statistically insignificant coefficients for 2017-18, 2018-19, and 2019-20 indicate that production remained relatively stable prior to this decline. Similarly, the productivity model showed no statistically significant differences among crops. Nevertheless, productivity declined significantly by 4.66 q ha⁻¹ during 2020-21 ($p < 0.001$), while changes observed during the preceding years were not statistically significant. These results indicate that the reduction in production observed during the final year was primarily attributable to declining productivity rather than reductions in cultivated area. The Random Effects panel regression models explained 22.40 percent, 22.30 percent, and 22.80 percent of the variation in area, production, and productivity, respectively. Furthermore, the highly significant Wald chi-square statistics confirmed the overall adequacy and statistical significance of the fitted models.

Table 5: Random effects panel regression estimates for area, production and productivity of temperate fruits in Uttarakhand (2016-17 to 2020-21)

Variables	Area (ha)	Production (MT)	Productivity (q ha ⁻¹)
Intercept	962.66* (408.21)	5112.85 (3537.85)	37.24* (17.99)
Apricot	-193.75 (577.28)	-595.70 (5001.52)	0.51 (25.42)
Peach	99.96 (577.28)	5223.52 (5001.52)	31.01 (25.42)
Plum	-15.82 (577.28)	788.88 (5001.52)	9.30 (25.42)
Walnut	137.95 (577.28)	-2752.52 (5001.52)	-18.24 (25.42)
Year 2017-18	9.36**	34.81	-0.04
Year 2018-19	11.88***	17.30	-0.23
Year 2019-20	14.06***	19.41	-0.36
Year 2020-21	15.86***	-629.36***	-4.66***
Observations	125	125	125
District × Crop Panels	25	25	25
R ²	0.224	0.223	0.228
Model Statistic	$\chi^2 = 33.478^{***}$	$\chi^2 = 33.382^{***}$	$\chi^2 = 34.284^{***}$
Selected Model	Random Effects	Random Effects	Random Effects

Notes: Figures in parentheses are standard errors for the intercept and crop coefficients. Apple is the reference crop, and 2016-17 is the reference year. Significance levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

4. Conclusion

The combined evidence from descriptive statistics, AGR, CAGR, and panel regression analysis indicates that temperate fruit cultivation in the Kumaon region underwent gradual spatial expansion during 2016-17 to 2020-21. However, increases in cultivated area were not consistently accompanied by improvements in production or productivity. Almora emerged as the dominant district for apple, plum, apricot, and walnut cultivation, whereas Nainital demonstrated a clear comparative advantage in peach production.

Both AGR and CAGR analyses consistently revealed positive trends in cultivated area but mixed trends in production and predominantly declining productivity for most crops. These findings suggest that the expansion of orchards alone is insufficient to ensure higher production unless accompanied by improvements in orchard management, rejuvenation of ageing plantations, adoption of high-yielding cultivars, balanced nutrient management, integrated pest and disease management, and climate-resilient production practices. The panel regression analysis further substantiated these findings by demonstrating a statistically significant increase in cultivated area over time, while production and productivity declined significantly

during the final year of the study. The absence of significant differences among crop categories indicates that temporal factors exerted a greater influence on cultivation dynamics than crop-specific characteristics. Thus, the findings emphasize that future development of temperate fruit cultivation in the Kumaon region should focus not only on expanding cultivated area but also on enhancing productivity through technological interventions, improved orchard management, climate adaptation strategies, and location-specific extension support. Such measures will be essential for achieving sustainable growth in temperate fruit production and strengthening the livelihoods of hill farmers in Kumaon region of Uttarakhand.

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