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Spatial Distribution and Concentration Dynamics of Apricot Production in the Districts of Malatya (2004–2024)

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ABSTRACT

This study aims to analyse, within the framework of human–nature interaction, the spatial relocation displayed by apricot production clusters across the districts and elevation belts of Malatya widely regarded as the leading centre of Türkiye's apricot production over the 2004–2024 period. Malatya carries a sharp morphological contrast between a tectonic depression plain (the Battalgazi-Yeşilyurt floor, ~850–950 m) and the plateaus extending from the mountainous masses 1,400–2,241 m in height that surround this plain to the north, west and south; this contrast constitutes the principal spatial variable of the study. The research uses twenty years of panel data compiled from the province- and district-level crop production statistics of the Turkish Statistical Institute (TÜİK); the analysis is supported by geographic information systems (GIS)-based mapping, intra-provincial concentration ratios (CR1, CR3), the Herfindahl-Hirschman Index (HHI) and the location-quotient (LQ) approach. The findings show that the distribution of production across the 14 districts is non-stationary: following the catastrophic 2014 spring frost, the intra-district HHI value rose from 1,089 to 1,563 as production concentrated in a small number of relatively sheltered districts, whereas by 2024 the HHI fell back to 1,317 as production re-dispersed but around a centre that had shifted from the plain to the plateau. Two geographic drivers of the spatial shift are identified: climate-change-driven phenological advancement increasing frost risk on the valley floors and steering growers toward the 1,200–1,900 m high plateaus (Akçadağ, Darende, Hekimhan); and, simultaneously, the loss of Class I and II alluvial land on the Battalgazi plain to agriculture under the pressure of urban sprawl. The results reveal that the apricot cluster is not a geographic constant but a dynamic spatial system continuously repositioned by climatic and anthropogenic pressures, and that micro-zoning, elevation-sensitive agricultural support and geographical-indication governance must take this dynamism into account.

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Introduction

Türkiye ranks by a wide margin first in world apricot (Prunus armeniaca L.) production, with an annual harvest varying between 750 thousand and 1.27 million tonnes, and holds a commanding position in this field with a market share exceeding 85% of world dried-apricot exports (Topçu and Uzundumlu, 2010; Ercisli, 2009). However, behind this national dominance lies an even more striking geographic concentration: almost half of Türkiye's production takes place within the boundaries of a single province, Malatya, which makes up only 1.6% of the country's surface area (Asma, 2007; Gezer, 1998). Characterised as the "Capital of Apricot", Malatya alone accounts for 50–54% of Türkiye's total fresh apricot production and 85–95% of its dried apricot production; across the province there are more than 8 million fruit-bearing apricot trees (Gündüz et al., 2020; Aslan, 2022). The water-soluble dry-matter content of Malatya apricots is reported to lie in the 22–28% range markedly above the 14–18% band of other domestic and foreign production basins according to the national apricot workshop findings of the Ministry of Food, Agriculture and Livestock (GTHB, 2014; reaffirmed in Hasdemir, 2025). This distinctive fruit-quality profile removes the geographic concentration of production in Malatya from being a mere statistical coincidence and points to a distinctive combination of soil, climate and topography (Tapan, 2023; Sunkar et al., 2013).

The geographic basis of this superiority must be sought not in Malatya itself being a uniform space, but on the contrary in its harbouring a sharp morphological contrast within the province. The province is built upon a complex geomorphological mosaic in the Upper Euphrates Section

of the Eastern Anatolia Region, ranging between 624 and 2,241 metres above sea level, where an alluvial depression plain interlocks with the high plateaus surrounding it (Erol et al., 1987; Balcıoğlu et al., 2022). The basin floor, which forms the administrative-physical centre of the province and is today divided into the districts of Battalgazi and Yeşilyurt, lies at 850–1,000 metres in elevation and is covered with fertile brown and alluvial soils of Class I, II and III land-use capability deposited by the tributaries of the Euphrates; this floor has traditionally been the heart of apricot horticulture (Özüpekçe, 2021). By contrast, the mountain-range extensions encircling the northern (Hekimhan, Arguvan, Kuluncak), western (Darende, Akçadağ) and southern (Doğanşehir) parts of the province rise as limestone and volcanic masses beginning at 1,200 metres and exceeding 1,800–2,000 metres; they are divided by the intra-valley flats carved by watercourses such as the Tohma Stream, the Şiro Stream and the Sultansuyu (Balcıoğlu et al., 2022).

This elevation gradient, when combined with the effect of the semi-arid continental climate, creates a geographically sensitive balance for apricot cultivation: lower elevations offer a warmer growing season and easier access to irrigation while being more exposed to late spring frosts; the high plateaus, although partly protected from frost risk, are traditionally confined to rain-fed agriculture and a shorter vegetation period (Avcı and Esen, 2019). Over the last twenty-year period (2004–2024) this balance has begun to break down. The roughly 2.4°C rise in mean annual temperatures between 1980 and 2020 advanced the phenological flowering stage of the apricot by about twenty days on average; while dramatically widening the frost-exposure window of the orchards on the basin floor, it rendered rain-fed apricot growing economically feasible at the high elevations formerly regarded as cold (Balcıoğlu et al., 2022; Avcı and Esen, 2019). In particular, the severe radiation and advection frosts experienced in 2004, 2010 and 2014 damaged almost all of the orchards on the basin floor, and in 2014 reduced provincial production to as low as 38,654 tonnes (Aslan, 2022; Balcıoğlu et al., 2022).

Simultaneously, another dynamic of human geography urban sprawl has begun to threaten the same basin floor from a different direction. The population and construction pressure of the Battalgazi and Yeşilyurt districts, which have grown with the Malatya city centre and the entry into force of metropolitan status in 2014, is rapidly removing from agriculture the Class I and II alluvial lands formerly covered with apricot orchards (Dağ, 2021; Cengiz and Yılmaz, 2016; Görmüş et al., 2018). As a result, the plain floor is under twofold pressure: climatic from above (frost risk) and anthropogenic from below (urbanisation). This double pressure suggests that apricot production does not display a stationary geographic distribution within Malatya; on the contrary, it experiences a continuous spatial shift and concentration dynamism between districts and elevation belts (Çağlıyan and Dağlı, 2017; Özüpekçe, 2021).

Internationally, the analytical toolkit used to measure such intra-regional reallocation concentration ratios, the Herfindahl-Hirschman Index and the location quotient is well grounded in regional science and economic geography, from Krugman's (1991) foundational treatment of the geography of trade and industrial concentration to Ellison and Glaeser's (1997) dartboard approach to measuring geographic concentration in U.S. manufacturing; this study adapts that toolkit, still rarely applied at the intra-provincial scale in the agricultural-geography literature, to Malatya's apricot-growing districts. At this point a critical question arises from the standpoint of the geography discipline: what kind of spatial pattern does this relocation under climatic and anthropogenic pressures follow at the district scale; in which direction, at what speed and to what extent does the production centre of gravity shift? More specifically, the study is guided by two research questions: (RQ1) how has the intra-provincial concentration of apricot production among Malatya's districts changed over the 2004–2024 period; and (RQ2) to what extent can this change be attributed to the elevation-belt frost-risk and urban-sprawl mechanisms identified in the literature? Building on the physical-human geography contrasts described above, the study's guiding hypothesis (H1) is that the production centre of gravity has shifted measurably from the plain floor toward the high-plateau belt over the study period, driven jointly by climate-induced frost risk on the valley floor and urban-sprawl-driven farmland loss on the plain. In the agricultural-geography literature, Malatya apricot growing has frequently been addressed through province-level aggregate figures or through economic-efficiency analyses at the enterprise scale; the inter-district spatial redistribution has been largely neglected. This study aims to fill that gap; it sets out to measure and map, with Geographic Information Systems and spatial concentration indices, the relocation displayed by Malatya's apricot production clusters across its 14 districts over the 2004–2024 period, placing the topographic and climatic internal differentiation of the province at the centre.

Literature Review and Significance of the Study

An examination of the literature shows that there is a rich body of scholarship investigating the technical, economic, marketing and climatic dimensions of apricot production at the Malatya scale. Nevertheless, the great majority of these studies have focused on sectoral analyses and province-level aggregate figures; the spatial dynamism of production at the district scale that is, geography's essential question of "where and why here" has been largely neglected.

The input use and economic efficiency of apricot enterprises is one of the most frequently treated themes in the literature. Gündüz (2015) measured the technical efficiency of enterprises in Malatya with Fuzzy Data Envelopment Analysis and modelled the optimum input combination for increasing efficiency. Külekçi et al. (2016) in Elazığ province, and Aslan (2013) and Aslan (2022) in Malatya province, carried out comparative socio-economic analyses of organic and conventional apricot enterprises and revealed their economic profitability ratios. Similar efficiency models were applied to various products and regions by Uçar (2011), Bayramoğlu and Gündoğmuş (2008), Ceyhan and Hazneci (2010), and Ören and Alemdar (2006); the socio-economic structures of small-scale producers were examined by Gündüz et al. (2023), identifying the bottlenecks in production. Although these studies offer valuable economic findings, they have not

treated the district or elevation belt in which the enterprises are located as an analytical variable.

Research focusing on the apricot's position in domestic and foreign markets, the intermediary factor, price instability and foreign-trade volume is also quite abundant. Çatı and Yıldız (2007) and Adanacıoğlu (2003) detailed the dried-apricot marketing problems in Türkiye and proposed solutions. Engindeniz and Uçar (2018), Öztürk and Karakaş (2017), and Atalan (1995) analysed the structural problems producers in Malatya face in accessing the market. While Sobutay (2003) discussed the risks in export processes, Çağatay (2019) carried out a comparative value-chain analysis in the Malatya and Mersin apricot markets, and Tapan (2023) emphasised the importance of geographical indications.

Climate and frost-risk management, the most critical element determining the apricot harvest, occupy an important place in the literature and directly feed the physical-geography foundation of this study. Balcıoğlu, Kaya and Demircan (2022) examined in depth the effects of climate change on the apricot harvest and its geographic distribution in Malatya, revealing phenological deviations and the trend toward rain-fed agriculture on the high plateaus. Uçar and Engindeniz (2019) and Çukur and Saner (2008) analysed producers' tendencies to use agricultural insurance against frost and the risk-transfer mechanisms. Gökkür and Şahin (2020) and Demircan et al. (2011) modelled the long-term effects of temperature increases and climate projections on fruit growing.

Studies addressing spatial changes in land use, although direct precursors of this research, are more limited in number. Dağ (2021) and Özüpekçe (2021) used remote sensing to detect the threats created by the rapid urbanisation of agricultural areas in the Malatya Plain. Çağlıyan and Dağlı (2017) and Bilgiç and Er (2025) mapped the areas suitable for fruit growing in the basin using GIS and the Analytic Hierarchy Process. As for future projections, Karabacak and Uzundumlu (2020), Şenyüz (2019) and Başaran Caner and Engindeniz (2020) performed apricot production forecasts with ARIMA models. However, none of these spatial studies has combined district-level production data over a long time span with a systematic set of concentration indices to measure the direction and speed of the production centre of gravity.

The existing literature has generally addressed the climatic crises, economic efficiency and marketing problems of apricot agriculture with cross-sectional data and at the province scale. However, no study has been found that, over a long-term period (2004–2024), maps with an integrated spatial-concentration model the production shifts experienced among the districts of Malatya, the climb toward the high plateaus triggered by escape from frost risk, and the way the urbanisation pressure in plain areas such as Battalgazi repositions the agricultural clusters. By integrating district-level production data, concentration indices and topographic-capability layers, this research aims to fill this geographic gap in the literature. The district-level production concentration indices and the spatial-shift pattern presented here provide decision-makers with a strategic infrastructure at the district and elevation scale for rural development, micro-zoning, agricultural-grant planning and geographical-indication governance.

Materials and Methods

Physical and Human Geography of the Study Area

The study area is Malatya province, located in the Upper Euphrates Section of the Eastern Anatolia Region, between the northern latitudes of 37°45'–39°08' and the eastern longitudes of 37°15'–39°00', with a surface area of approximately 12,265 km². The province can be divided geomorphologically into three main units: (i) the tectonically originated Malatya Plain (Battalgazi-Yeşilyurt floor, ~850–1,000 m), which forms the administrative and historical core of the province and lies near the point where the Euphrates River joins the Karakaya Dam Reservoir; (ii) the northern plateau belt at 1,000–1,800 m in elevation that surrounds the plain from the north and contains the districts of Hekimhan, Arguvan and Kuluncak; (iii) the western-southern mountainous-plateau belt that bounds the plain from the west and south, covering the districts of Darende, Akçadağ and Doğanşehir and reaching 2,241 metres in places (Erol et al., 1987; Balcıoğlu et al., 2022). The elevation difference between these three units reaches 1,600 metres; this leads to two virtually distinct agroecological environments existing side by side within the same provincial boundaries. It should be stressed that these three physiographic units serve here as descriptive regional context rather than as the study's analytical unit: the production analysis itself is conducted at the district level (see Data Sources and Method below), so that the non-cultivable higher mountain surfaces within the northern and western-southern belts which lie well above the orchard line and are not under apricot cultivation do not enter the reported production figures; only the cultivated lower slopes, valley segments and plateau surfaces of the districts located within each belt contribute to the statistics analysed.

Hydrographically, the area is drained by the Tohma Stream (western and north-western section), two important tributaries of the Euphrates River, and by the Sultansuyu and Kuruçay (southern section); the intra-valley flood plains and alluvial fans of these watercourses have formed the secondary concentration areas of traditional apricot horticulture (Sunkar et al., 2013). The soil cover consists, on the plain floor, of deep clayey-loamy alluvial soils and brown forest soils with Class I and II land-use capability, while on the high plateaus shallower brown and reddish-brown soils derived from limestone bedrock predominate (Balcıoğlu et al., 2022). The climate type, in the transition belt between Mediterranean and continental climate characteristics, has a semi-arid continental character; winters are cold and partly snowy, summers are hot and dry, and annual precipitation remains in the 350–450 mm band. For an early-flowering fruit species such as the apricot, this climate type carries both an advantage (the sunshine duration that allows high dry-matter accumulation) and a risk (exposure to late spring frosts).

Figure 1 visualises these elevation belts through the digital elevation model (DEM) of the province: the flat-to-rolling surface of the plain floor in green tones forms a sharp contrast with the high and dissected surface in yellow-brown tones of the plateaus surrounding it. Figure

2 presents the same topographic base together with the district settlement points and the watercourse network; it shows that the district centres are largely established on valley floors and alluvial fans, so that agricultural settlement is also tightly bound to topography. This elevation gradient forms the geographic ground of the study's principal argument — the "escape from frost risk / climb to the high plateaus" process; all the spatial analyses presented below are interpreted with reference to this three-unit structure.

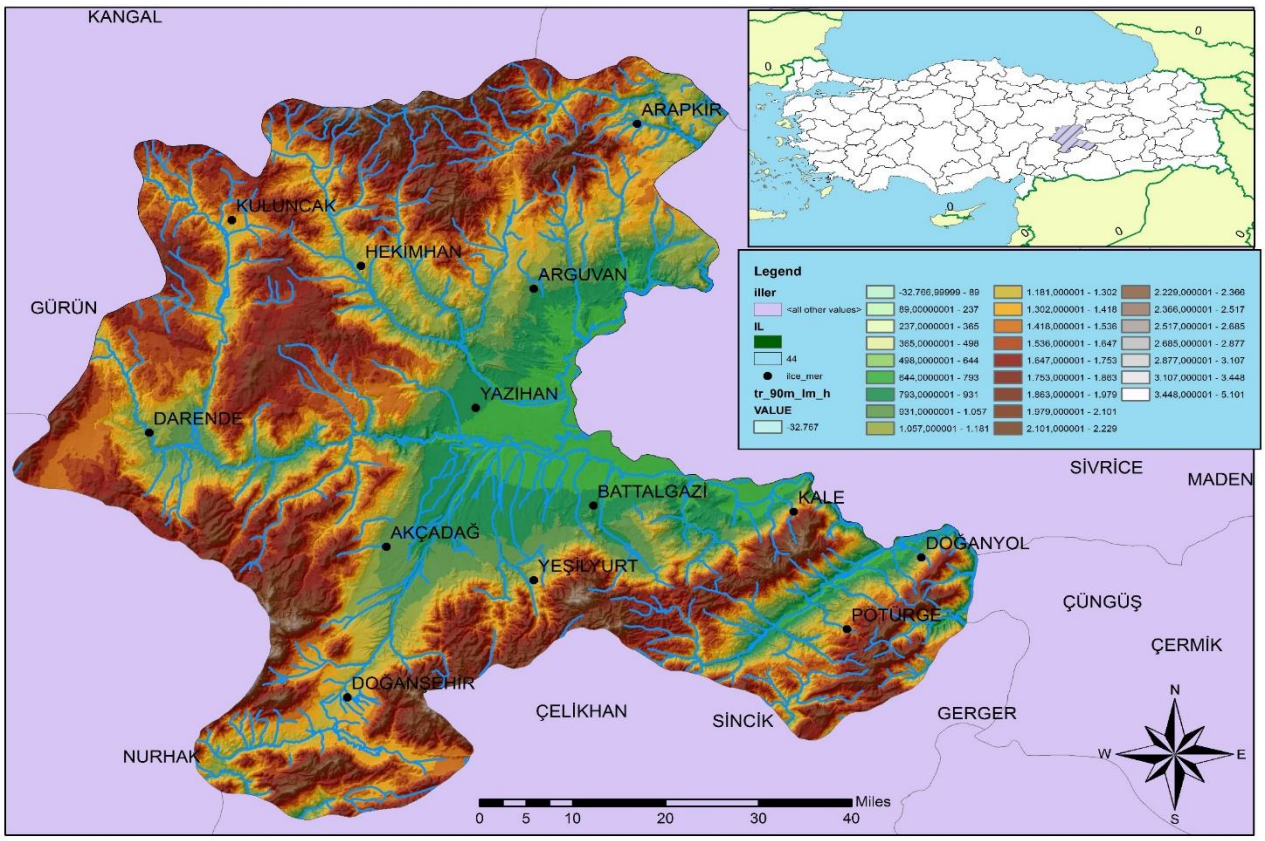


Figure 1. Digital elevation model (DEM) of Malatya province and elevation belts (m). Green tones represent the plain floor (624–1,076 m), and yellow-brown tones the high plateau and mountainous belt (1,076–2,241 m).
Source: Produced by the author using TÜİK province/district boundaries and SRTM 90 m DEM data

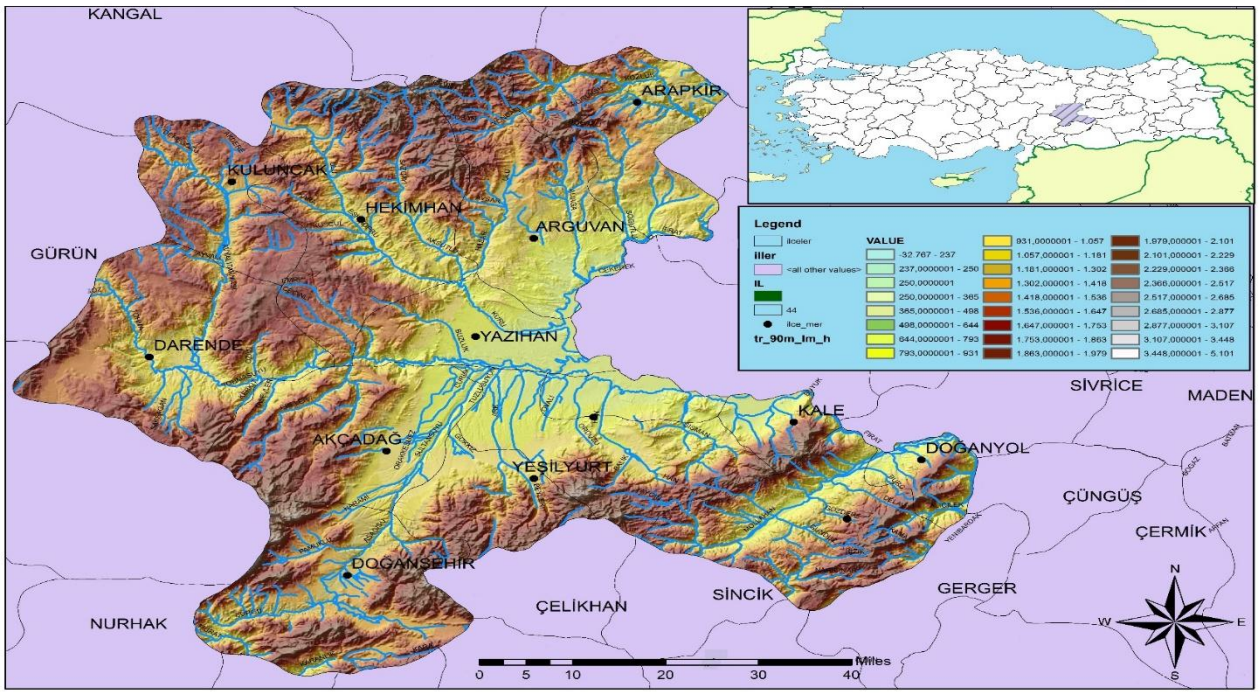


Figure 2. Map of Malatya district settlement points, watercourse network and topographic base.
Source: Produced by the author using TÜİK province/district boundaries and SRTM 90 m DEM data

Data Sources

To measure the spatial shift and concentration dynamism, twenty-one years of time-series (panel) data covering the years 2004–2024 were used. The primary dataset consists of the annual apricot production (tonnes) figures for Malatya's 14 districts compiled from the Crop Production Statistics of the Turkish Statistical Institute (TÜİK). These data were cross-checked against the Farmer Registration System (ÇKS) records of the Ministry of Agriculture and Forestry, Malatya Provincial Directorate. For the topographic analyses, the Digital Elevation Model (DEM, 90 m resolution), administrative boundary layers and major soil group maps were included in the material set (Bilgiç and Er, 2025; Özüpekçe, 2021). Where deemed necessary, the district-scale findings were related — solely as a contextual frame of reference — to the provincial- and national-scale aggregate production figures of TÜİK and FAOSTAT/Our World in Data.

As an important methodological note, with Law No. 6360 on Metropolitan Municipalities that entered into force in 2014, the former "Centre" district of Malatya was administratively split into two as Battalgazi and Yeşilyurt; for this reason Centre appears in the dataset as a separate unit only in the 2004 cross-section, while in subsequent periods its production is distributed between these two new districts. This administrative break is clearly noted in the district-level time-series comparisons and is incorporated into the interpretation.

Method

In the research, Geographic Information Systems (GIS), spatial concentration statistics and trend analyses were used together to model the intra-district spatial changes of apricot production volumes between 2004 and 2024.

Concentration and clustering measures. To measure the degree to which production is gathered in a small number of districts, concentration ratios (CR1, CR3) and the Herfindahl-Hirschman Index (HHI) were calculated. The HHI is defined as the sum of the squares of each district's percentage share in total provincial production; below 1,500 is interpreted as low, between 1,500 and 2,500 as moderate, and above 2,500 as high concentration. The analysis was conducted among Malatya's 14 districts to obtain "intra-provincial concentration" indicators. The relative weight of the districts within the province as a whole was assessed using the Location Quotient (LQ) approach; thus the vectorial shift in the production centre of gravity was determined.

$$CR_n = \Sigma\, s_i \quad (1)$$

$$HHI = \Sigma\, s_i^2 \quad (2)$$

$$LQ_i = (x_i / X) / (a_i / A) \quad (3)$$

Here s_i denotes the percentage share of the relevant district in total provincial production, and n the number of districts considered. In the location quotient, x_i denotes the production of district i, a_i the total fruit-growing area of the district, and X and A their provincial totals.

Volatility analysis. The year-to-year instability in district production was measured with the coefficient of variation (CV = standard deviation / mean). A high CV reflects the vulnerability of production to climatic shocks and periodicity.

$$CV = (\sigma / \mu) \times 100 \quad (4)$$

Growth and trend analyses. Long-term growth was compared with the Compound Annual Growth Rate (CAGR), and relative growth rates with index analysis (2004 = 100).

$$CAGR = (V_t / V_0)1/t - 1 \quad (5)$$

Here V_t and V_0 denote, respectively, the end-of-period and beginning-of-period values, and t the number of years.

GIS analyses. Malatya's district boundaries, geomorphological units, digital elevation models and major soil groups were layered in the ArcGIS environment; the districts' production values in different years were overlaid with these layers to produce spatial-distribution patterns (Çağlıyan and Dağlı, 2017; Dağ, 2021). The linear relationships between variables were examined with the Pearson correlation coefficient.

$$r = \Sigma(x_i - \bar{x})(y_i - \bar{y}) / \sqrt{[\Sigma(x_i - \bar{x})^2\, \Sigma(y_i - \bar{y})^2]} \quad (6)$$

Here $\bar{x}$ and $\bar{y}$ are the arithmetic means of the variables; the coefficient takes values between −1 and +1.

Findings

Malatya's Position in the National Frame: A Brief Context

Before moving on to the intra-district spatial analysis, it is necessary to position briefly the magnitude and volatility of Malatya's production volume; for the district-scale findings to be presented below are an unfolding of how this magnitude is distributed within the provincial boundaries. Over the 2004–2024 period Malatya's production rose from 84,706 tonnes to 690,730 tonnes, recording an extraordinary total increase of 715.4% (CAGR 11.06%); this increase did not follow a straight line but, particularly in the 2014 frost year, experienced a sharp collapse falling to as low as 38,654 tonnes (Figure 3). Over the same period Malatya alone met on average 52% of Türkiye's production and at times 15% of world production; it reached a geographic-monopoly position made concrete by the rise of the inter-provincial HHI at the national scale from 1,708 to 3,277. The descriptive statistics of the production variables (Table 1) reveal that, with a 42.8% coefficient of variation, Malatya carries volatility that is relatively stable among major producers yet still high in absolute terms; and that the correlation between production and planted area remains at only 0.40, showing that the annual harvest is determined not by the size of the area but by that year's climate conditions. This finding directly necessitates the study's main question which districts and which elevation belts within the province this climatic vulnerability affects differently.

Inter-District Spatial Distribution and Clustering Dynamism

This section, which forms the original contribution of the study, carries the analysis directly into Malatya and addresses the relocation of production clusters among the 14 districts.

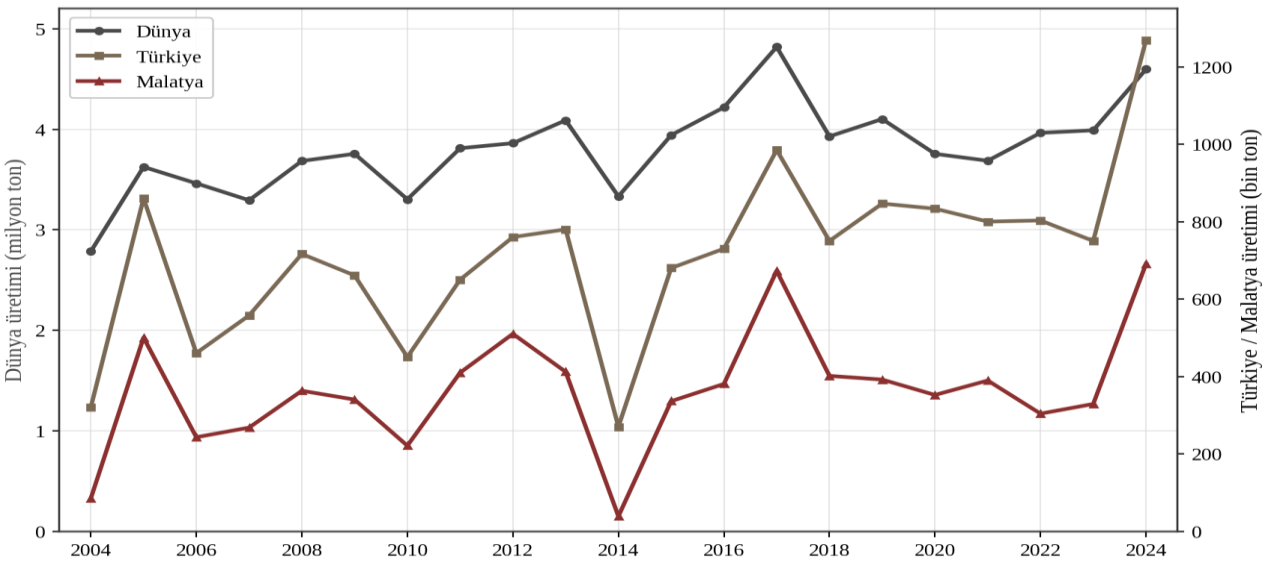


Figure 3. Annual course of Malatya apricot production (2004–2024, tonnes). The world and Türkiye series are shown only as a scale reference

Source: Calculated by the author from TÜİK data

Table 1. Basic descriptive statistics and selected indicators of Malatya apricot production (2004–2024).

Indicator	Value
Mean Production (Tonnes)	363,651
Standard Deviation (Tonnes)	155,564
Minimum (2014)	38,654 tonnes
Maximum (2024)	690,730 tonnes
Coefficient of Variation (CV)	42.8%
Total Change 2004–2024	715.4%
Compound Annual Growth Rate (CAGR)	11.06%
Average Share in Türkiye's Production	52%
Production–Planted Area Correlation (R)	0.40

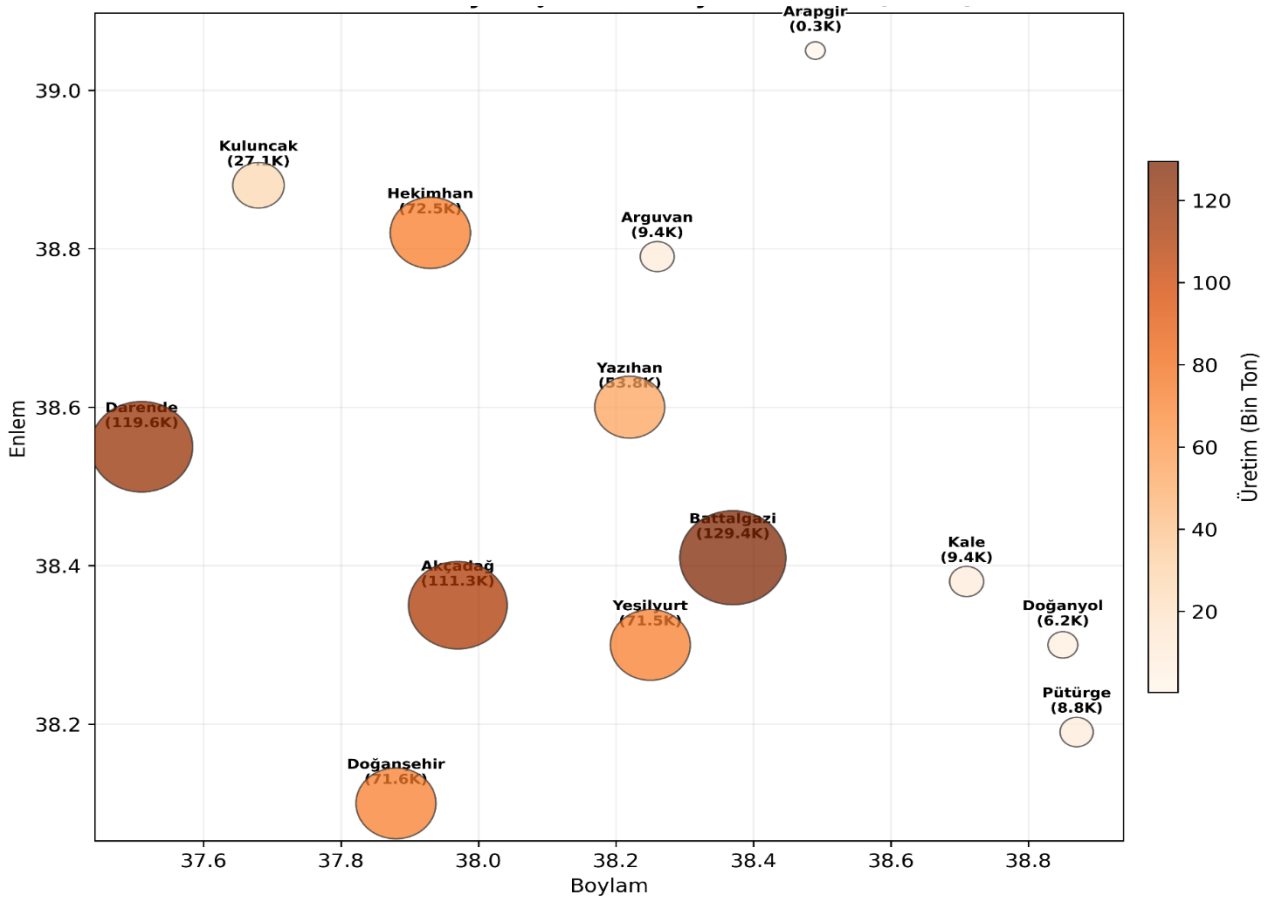
The district-level production data (Table 2) lay bare a dramatic repositioning over the 2004–2024 period. As noted earlier, with the metropolitan reform of 2014 the former "Centre" district was split into two as Battalgazi and Yeşilyurt; for this reason Centre appears only in the 2004 cross-section.

Table 2 reflects the macro-level change and structural breaks of the districts of Malatya over a twenty-year span (2004–2024). When the data are examined as a whole, it is seen that total provincial output, which was 84,706 tonnes in 2004, fell to 38,654 tonnes in 2014 through an asymmetric contraction of about 54%, and in 2024 reached 690,730 tonnes with an astronomical increase exceeding 1,680%. While this sudden collapse in 2014 emerged as a destructive meteorological shock in the districts on the western/northern axis such as Akçadağ, Darende and Hekimhan, which by their geographic location are close to the valley floor and the low plateau, the districts in the eastern part of the province located in the more enclosed and relatively sheltered sections of the Euphrates valley such as Doğanyol, Pütürge and Kale on the contrary recorded growth and functioned throughout the period as geographic buffer zones for the system. This opposite direction clearly shows that the province is not a single climatic-topographic unit and that frost risk is not homogeneously distributed within the province.

The clearest administrative-geographic break in the table reveals itself in the fact that the "Centre" district produced data only in 2004 and dropped out in subsequent periods.

This is a direct consequence of Law No. 6360, which entered into force in 2012 and carried Malatya to metropolitan status; the former centre was abolished and its institutional database was transferred to the districts of Battalgazi and Yeşilyurt. Indeed, the exponential growth over time of the districts of Battalgazi (2,316 → 129,430 tonnes) and Yeşilyurt (956 → 71,500 tonnes) confirms both this administrative merger and the shift of the province's economic and demographic agglomeration (the clustering at the centre) toward these two plain focal points an indication of the human-geographic weight of the urban core reflected even in agricultural statistics.

The extraordinary growth explosion observed between 2014 and 2024, affecting all districts (except Doğanyol), is too radical to be explained by an organic development model. In particular, Battalgazi, Darende and Akçadağ exceeding the 100,000-tonne threshold probably symbolises macro-level rehabilitation funds transferred to the region, infrastructure and irrigation investments, or nominal jumps not adjusted for inflationary effects. In this process, Doğanyol declining in 2024 in decoupling from the general trend, and Arapgir's rigid/change-resistant structure across all periods owing to its marginal location at the north-easternmost tip of the province, outside the sphere of influence of the apricot cluster reveal how different the geographic and micro-economic sensitivities of the districts to macro shocks are from one another.



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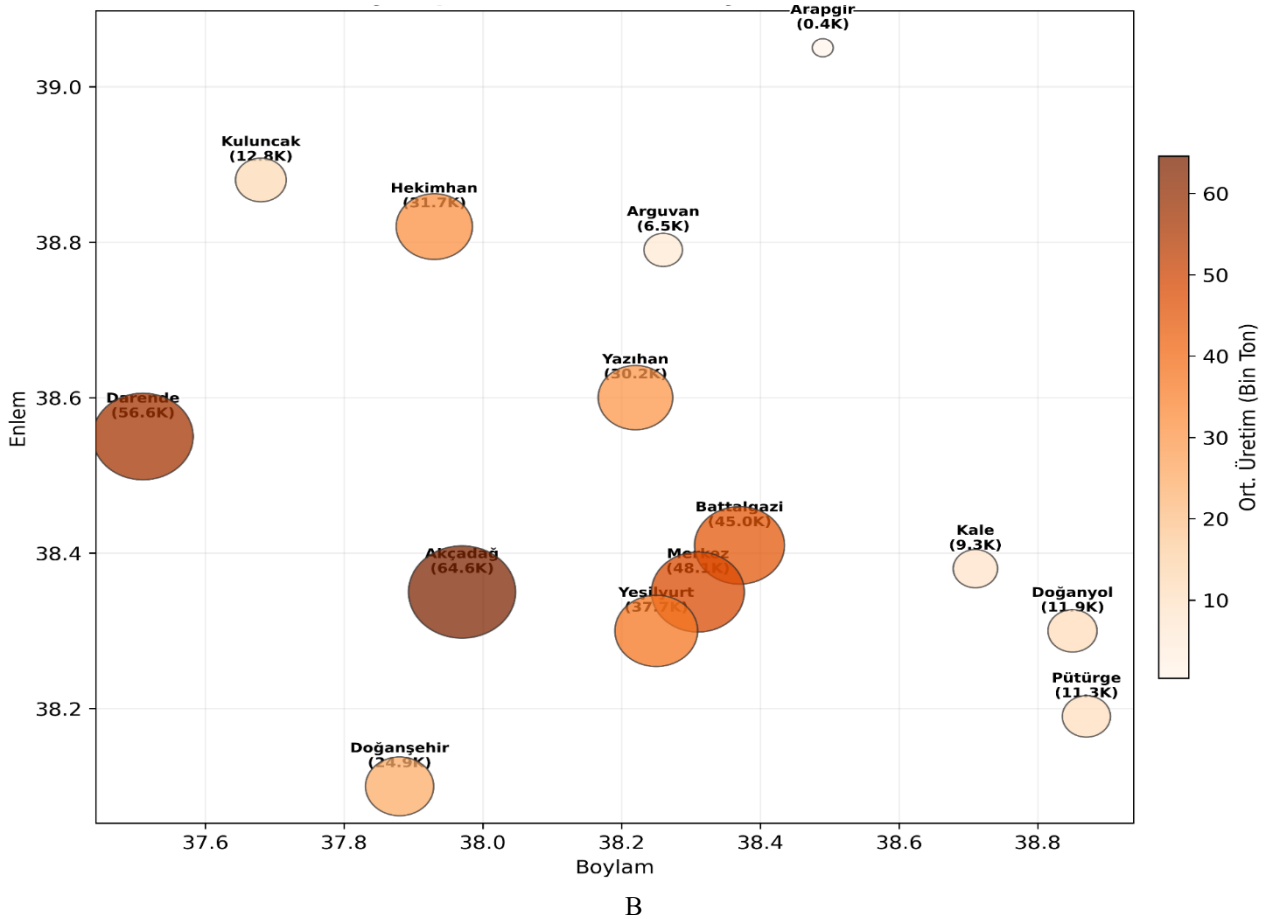

B

Figure 4. A) Clustering of apricot production in Malatya as of 2024. B) Shift of total inter-district production from 2004 to 2024

Figure 4 A (2024 cross-section) displays a three-polar structure: Battalgazi (129.4K) on the plain floor, and Akçadağ (111.3K) with Darende (119.6K) in close positions on the western-north-western plateau belt, form three heavy bubbles of almost equal size. Around these, Hekimhan (72.5K), Yeşilyurt (71.5K) and Doğanşehir (71.6K) form a second ring, while the eastern valley corridor (Kale, Doğanyol, Pütürge, Arapgir) remains visually almost imperceptibly small. This is the spatial counterpart of the article's finding that CR3 (Battalgazi+Darende+Akçadağ) fell to 52.2% in 2024: although concentration has come down from its 2014 peak, production is still dependent on three large foci now one of plain and two of plateau origin.

Figure 4 B (period average), by damping out the noise of a single cross-section year, reveals the structural trend, and there is a notable difference here: in the period average Akçadağ (64.6K) stands as the largest bubble, leaving behind Darende (56.6K) and even Battalgazi (45.0K). The reason for this is that Akçadağ's relatively high starting value in 2004 (15.8K) pulls the average upward; although Darende and Battalgazi overtake it when 2024 is viewed alone, Akçadağ's steady contribution stands out in the 20-year average. This is an observation directly consistent with the article's note (stated in the Table 2 explanation) that "the period average does not coincide one-to-one with the final cross-section".

On the second map, moreover, Centre the reappearance of the district (48.1K) a category no longer present on the 2024 map makes concrete how the administrative break (the splitting of Centre into Battalgazi and Yeşilyurt with the 2014 metropolitan reform) affects the average calculation: because Centre exists only in the 2004 cross-section, it enters the whole-period average with that single year's value alone, which shows it unrealistically high in volume (with a bubble even larger than Battalgazi). This had already been flagged in the article's methodological note as a break that "must be clearly noted in district-level time-series comparisons".

In general, when the two maps are read together, they reveal that the plateau belt (Akçadağ-Darende-Hekimhan) shows a consistent rise throughout the period rather than being the product of a single crisis year; whereas the plain belt (Battalgazi-Yeşilyurt), although appearing more modest in the period average, made a sharp jump in 2024 which adds a further nuance to the article's thesis of "a peripheral rise stemming not from the economic weakness of the centre but from its loss of climatic resilience": the plain, unlike the plateau, can still display a strong recovery capacity in recent years.

Table 2. District-level apricot production in Malatya (tonnes) — selected years and period average.

District	2004	2014	2024	Period Avg.
Akçadağ	15,804	668	111,265	64,596
Darende	14,135	2,780	119,563	56,647
Battalgazi	2,316	2,819	129,430	44,996
Yeşilyurt	956	2,946	71,500	37,695
Hekimhan	10,125	1,699	72,457	31,725
Yazıhan	6,240	962	53,786	30,233
Doğanşehir	5,925	0	71,607	24,932
Kuluncak	5,520	1,847	27,064	12,827
Doğanyol	6,400	8,911	6,226	11,881
Pütürge	3,060	8,331	8,753	11,329
Kale	4,680	7,250	9,439	9,304
Arguvan	3,792	315	9,357	6,473
Arapgir	128	126	283	402

Source: Calculated by the author from TÜİK district-level crop production statistics. Note: "Period Avg." is the mean of the complete uninterrupted 2004–2024 annual series for each district, not the simple arithmetic mean of the three cross-section years (2004, 2014, 2024) shown in this table; it therefore does not average the displayed columns directly.

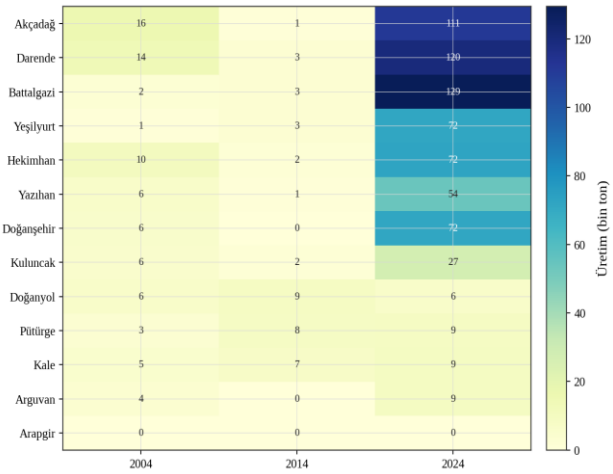

Figure 5. Heat map of apricot production in the districts of Malatya (2004 / 2014 / 2024, thousand tonnes)
Source: Calculated by the author from TÜİK data.

Moreover, the fact that the "Period Average" column is not equal to the simple arithmetic mean of the three years given in the table shows that this statistic rests on an uninterrupted time-series analysis in the background that also covers all the intervening years between 2004 and 2024. For example, the Centre district, whose active period was short, ranking third with a high average of 48,091 tonnes is a result of its dominant weight in past years. In short, this dataset reveals how administrative reforms affect the data distribution, how spatial roles change in crisis periods, and how the massive external shocks of the last decade have reshaped Malatya's agricultural geography from the ground up.

The district heat map (Figure 5) and the trend graph of the leading districts (Figure 6) reveal three fundamental geographic patterns. First, the 2014 frost catastrophe collapsed almost all districts simultaneously, pulling production to the floor; however, it is seen that districts close to the valley floor and the low plateau, such as

Akçadağ (668 tonnes) and Yazıhan (962 tonnes), were struck far more severely than the others this coincides with the known climatological mechanism whereby cold air, by "pooling" (temperature inversion) within valleys, forms more severe frost in the lower sections. Second, by 2024 production not only recovered but reorganised around new centres; Battalgazi (129,430 tonnes), Darende (119,563 tonnes) and Akçadağ (111,265 tonnes) stand out, while Doğanşehir and Yeşilyurt also rose strongly. Third, the valley-floor / high-plateau contrast became more pronounced; while the traditional floor lands lost their relative weight, the plateau and southern districts increased their shares.

This dynamism is even clearer when quantified with intra-provincial concentration indices. The inter-district HHI was 1,089 in 2004 (moderate-low concentration), whereas in the 2014 frost year it surged to 1,563; because the catastrophe gathered production in a small number of relatively sheltered districts. By 2024 the HHI fell back to 1,317, showing that production re-dispersed — but around a shifted centre. The three-district concentration ratio (CR3) follows the same pattern, rising from 47.3% in 2004 to 63.4% in 2014 and falling to 52.2% in 2024 (Figure 6, Table 3). This "rise–fall" pattern proves that clustering is not stationary; it is a dynamic process intensified by the climatic shock and then dissolved by geographic redistribution. From the standpoint of geographic theory, this pattern can be read as a classic centre-periphery reorganisation in which a regional system responds to an external shock (frost) first by spatial contraction (gathering at crisis centres) and then by adaptive re-dispersal (broadening through escape from risk). The shift in production composition is seen most clearly through a direct comparison of shares (Figure 7). Between 2004 and 2024 the production centre was markedly redistributed; the dominance of a single district gave way to a more balanced but geographically shifted pattern. On a period-average basis, Akçadağ (16.52%), Darende (14.48%) and Battalgazi (11.50%) share the top three ranks; these three centres represent, respectively, the high-plateau (Akçadağ-Darende) and plain-urban-edge (Battalgazi) typologies (Table 4).

Despite Battalgazi's high share in the period average, the fact that the district's alluvial flats are under urban-sprawl pressure indicates that this share will continue to shift toward the high plateaus in the medium term. Figure 9 translates this same rise–re-dispersal cycle into explicit spatial form across three cross-section panels (2004, 2014, 2024), with bubble size and colour representing each district's production volume.

The 2004 panel shows a scattered, multi-centred structure with no dominant district, consistent with that year's low HHI (1,089) and CR3 (47.3%). The 2014 panel visibly contracts around a small number of relatively sheltered eastern-valley districts (Doğanyol, Pütürge, Kale) as the frost-year concentration peak (HHI 1,563; CR3 63.4%) takes spatial form, consistent with the cold-air-drainage buffering hypothesis discussed above. The 2024 panel then shows both an explosion in overall volume and a bipolar centre of gravity split between the plain (Battalgazi-Yeşilyurt) and the high plateau (Akçadağ-Darende-Hekimhan-Yazıhan), while the eastern valley corridor's earlier relative advantage recedes indicating that its 2014 resilience reflected that specific frost event's spatial footprint rather than a structural, permanent advantage.

When the three panels are read in succession, the picture that emerges is not a linear growth but a spatial narration of the rise–fall curve of the HHI in the form 1,089→1,563→1,317: the scattered multi-centredness of 2004 underwent a temporary contraction under crisis in 2014, and in 2024 transformed into a structure re-dispersed at greater volume but into a different geography shifted from the plain to the plateau. This directly visualises the thesis that clustering is not a fixed geographic datum but a dynamic spatial system continuously repositioned by climatic shocks.

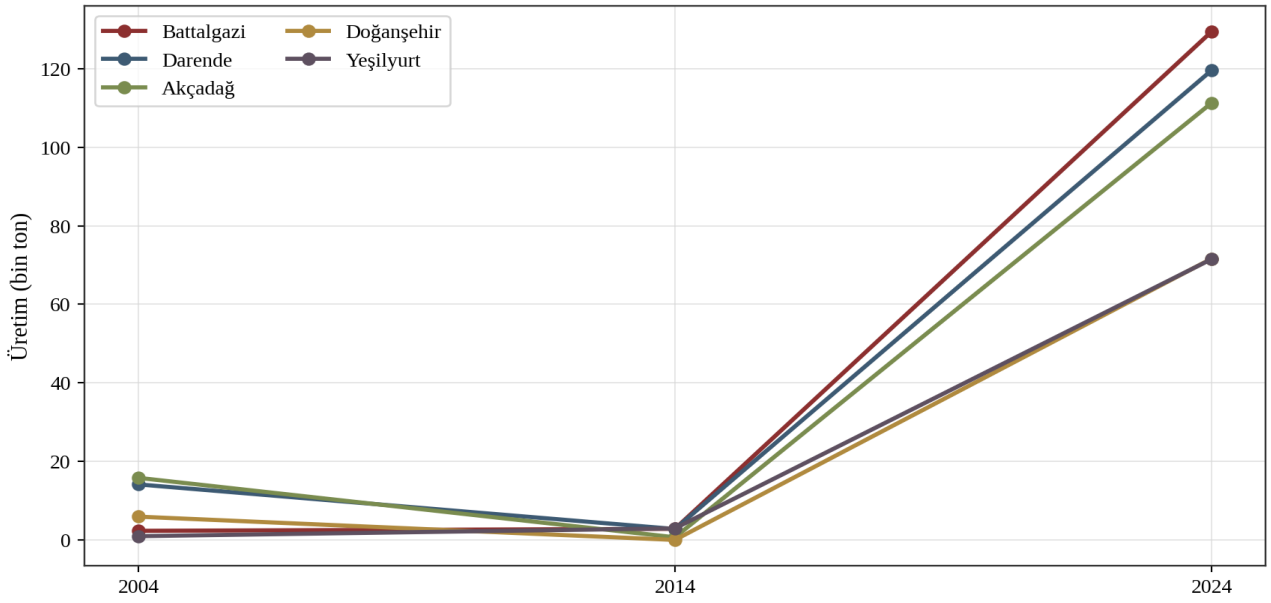

Figure 6. Apricot production trend of the five prominent districts of Malatya (2004 / 2014 / 2024)
Source: Calculated by the author from TÜİK data.

Table 3. Intra-provincial (inter-district) concentration indicators of Malatya — calculated values.

Year	Intra-Provincial HHI	Intra-Provincial CR1 (%)	Intra-Provincial CR3 (%)	Active Districts (n)
2004	1,089	18.7	47.3	14
2014	1,563	23.1	63.4	12
2024	1,317	18.7	52.2	13

Source: Calculated by the author from TÜİK district production data. HHI = Σ(share)²; CR1/CR3 the intra-provincial share of the largest 1 and 3 districts.

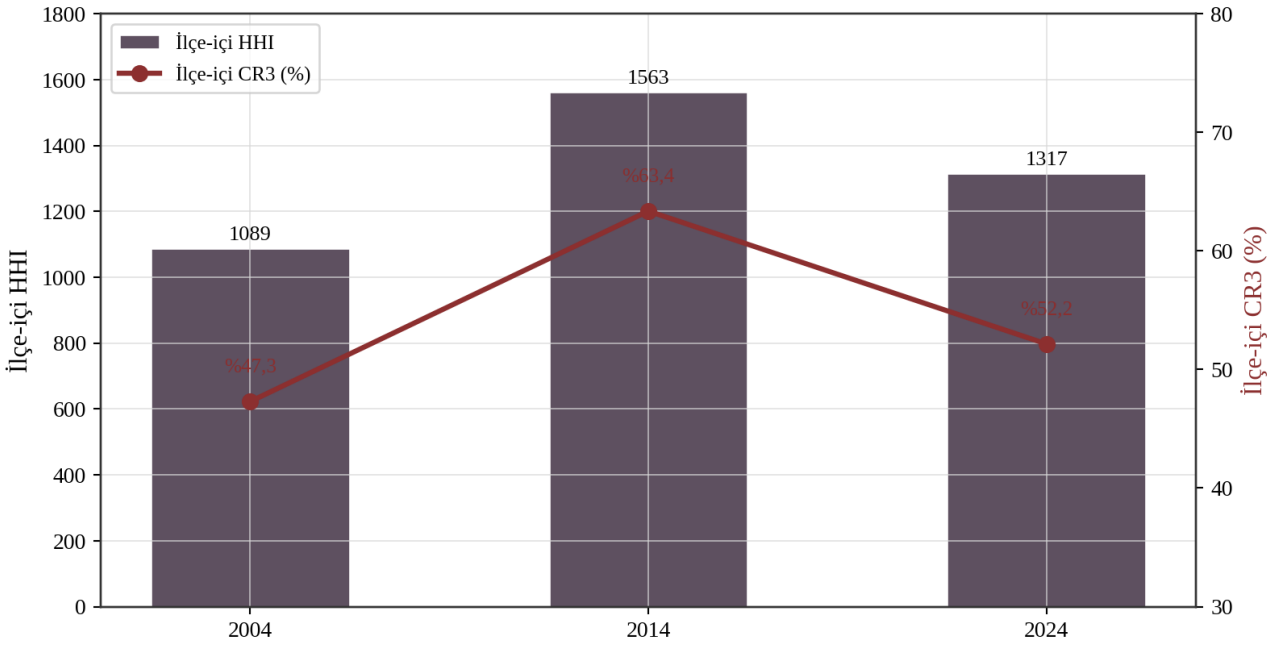

Figure 7. Intra-provincial production concentration of Malatya inter-district HHI and CR3 (2004 / 2014 / 2024).
Source: Calculated by the author from TÜİK data.

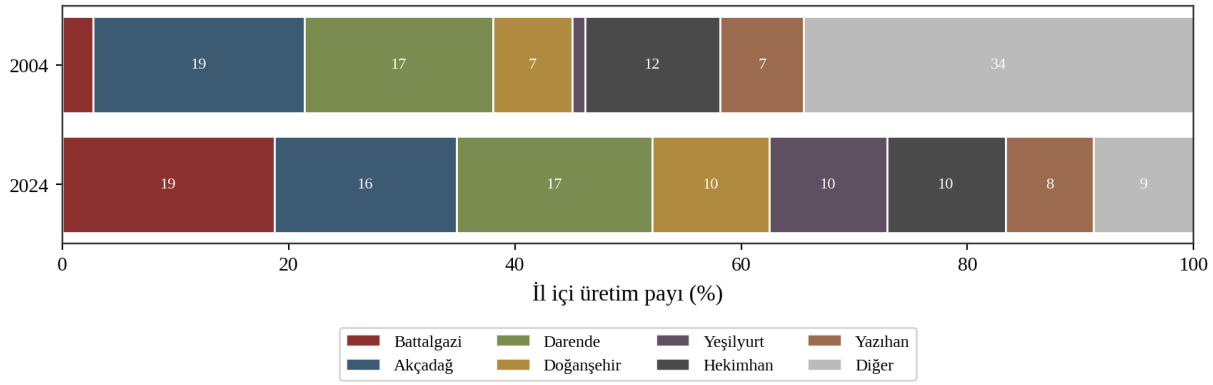

Figure 8. Composition of the intra-provincial production share of the districts of Malatya: 2004 versus 2024 (%)Source: Calculated by the author from TÜİK data.

Table 4. Period-average production share and ranking of the districts of Malatya (2004–2024).

Rank	*District*	*Mean Production (Tonnes)*	*Share (%)*
1	Akçadağ	64,596	16.52
2	Darende	56,647	14.48
3	Centre	48,091	12.30
4	Battalgazi	44,996	11.50
5	Yeşilyurt	37,695	9.64
6	Hekimhan	31,725	8.11
7	Yazıhan	30,233	7.73
8	Doğanşehir	24,932	6.37
9	Kuluncak	12,827	3.28
10	Doğanyol	11,881	3.04
11	Pütürge	11,329	2.90
12	Kale	9,304	2.38
13	Arguvan	6,473	1.65
14	Arapgir	402	0.10

Source: Calculated by the author from TÜİK data.

Figure 9. Spatial shift of apricot production in the districts of Malatya (2004 – 2014 – 2024)

Spatial Synthesis by Elevation Belts

To fully reveal the geographic meaning of the district-level findings, the 14 districts were classified into three elevation-position belts according to the topographic structure presented in Figure 1: (i) the plain floor and its immediate surroundings (Battalgazi, Yeşilyurt, Centre; ~850–1,000 m), (ii) the northern and western high plateaus (Akçadağ, Darende, Hekimhan, Yazıhan, Kuluncak, Arguvan; ~1,100–1,800 m), and (iii) the eastern-southern Euphrates valley corridor (Doğanşehir, Pütürge, Kale, Doğanyol, Arapgir; variable elevation, but under the heat-buffering effect of the river valley). When the period-average shares are summed across this three-way classification, the plain-floor belt makes up 33.4% of total production (Battalgazi+Yeşilyurt+Centre), the high- lateau belt 53.9% (Akçadağ+Darende+Hekimhan+Yazıhan+Kuluncak+Arguvan), and the eastern-southern valley corridor 12.7% (Doğanşehir+Pütürge+Kale+Doğanyol+Arapgir) (Table 5).

This aggregation directly confirms the central thesis of the study: even in the period average, more than half of production (53.9%) now takes place not on the plain floor but in the high-plateau belt. This ratio was at a much lower level in the 2004 cross-section in that year, while Akçadağ and Darende were still producing at relatively modest volumes (15,804 and 14,135 tonnes respectively), the plain-floor districts (Centre foremost) were dominant. In the 2024 cross-section, the total of the high-plateau districts (Akçadağ 111,265, Darende 119,563, Hekimhan 72,457, Yazıhan 53,786 tonnes) has approached the total of the plain-floor districts (Battalgazi 129,430, Yeşilyurt 71,500 tonnes), and indeed the plateau belt has spread over a broader base in terms of the number of districts. This means that the thesis that "the apricot cluster has climbed from the plain to the plateau" is supported by final-cross-section data and not only by the average.

The fact that the share of the eastern-southern valley corridor remains low (12.7%) but stable throughout the period is also geographically explanatory: these districts (especially Doğanyol, Pütürge, Kale) both have a land-soil structure historically less suited to apricot growing and the deeply dissected topography of the Euphrates valley limits large-scale orchard establishment. By contrast, the fact that these districts were far less affected in the 2014 frost year (Doğanyol's production rising, on the contrary) points to their intra-valley positions possibly being relatively advantageous in terms of cold-air drainage; this situation awaits confirmation by future station-based climatological studies.

Table 5. Aggregated production share by elevation-position belts (period average, 2004–2024).

Belt	Districts Covered	Approximate Elevation	Share (%)
Plain floor	Battalgazi, Yeşilyurt, Centre	850–1,000 m	33.4
High plateau	Akçadağ, Darende, Hekimhan, Yazıhan, Kuluncak, Arguvan	1,100–1,800 m	53.9
Eastern-southern valley corridor	Doğanşehir, Pütürge, Kale, Doğanyol, Arapgir	Variable (valley floor)	12.7

Source: Calculated by the author by grouping the data of Table 4.

Production-Area Relationship and Correlation Findings

The infrastructure of the structural change in production volume is the planted area. The apricot planted area in Malatya rose from 636,980 decares in 2004 to 944,900 decares in 2024; however, this 48.3% increase in area remained far below the 715.4% increase in production. This mismatch stems from the extraordinary fluctuation in Malatya's yield performance: provincial yield swings between 50 kg/decare (the 2014 frost year) and 832 kg/decare (2017), with a coefficient of variation of 40.6%. The fact that the correlation between production and planted area remains at only r=0.40 statistically confirms that what determines annual production in Malatya is not the size of the planted area but that year's climate conditions and frost events (Figure 8). This weak bond points to a geographically critical conclusion: the expansion of orchard area for example, new planting on the high plateaus does not by itself secure production; what is decisive is in which elevation belt and which microclimatic position the planted land is located.

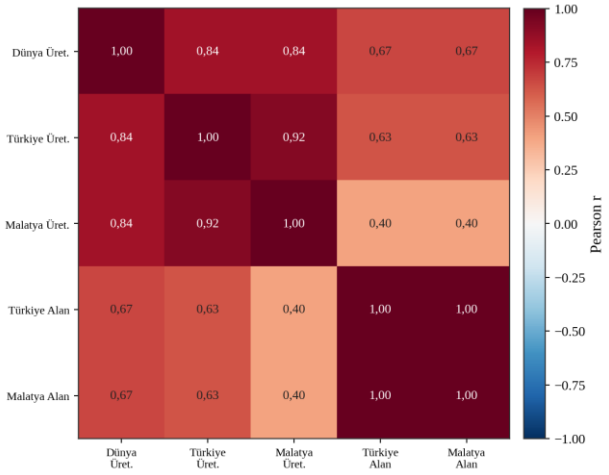

Figure 10. Pearson correlation matrix among the main variables (2004–2024)

Source: Calculated by the author from TÜİK data.

Discussion

The findings of this study reveal that apricot production in Malatya is not merely a story of volume magnitude; it is at the same time a dynamic spatial process continuously relocating within the provincial boundaries and shaped by ecological and demographic pressures. The fact that the correlation between production and planted area remains at only 0.40 confirms that the source of the system's fragility is not capacity shortage but annual climate conditions especially late spring frosts. This finding supports quantitatively at the district level, and carries one step further, the climate-driven harvest-volatility thesis emphasised by Balcıoğlu et al. (2022) and Çukur and Saner (2008).

The original contribution of the study is that it reveals the intra-provincial spatial projection of this volatility. The calculated district-level concentration indices show that the clustering structure did not remain stationary throughout the period: the district HHI value was 1,089 in 2004, rose to 1,563 in the 2014 frost-catastrophe year, and fell back to 1,317 in 2024, re-dispersing in part. In the same way, the share of the top three districts (CR3) was 47.3% in 2004, climbed to 63.4% in 2014, and fell to 52.2% in 2024. This "rise–re-dispersal" pattern suggests that in crisis years production gathered in a small number of relatively sheltered districts, after which producers, along with escape from frost risk, moved the production centre of gravity from the basin floor to the higher plateaus. The digital elevation models in Figure 1 and Figure 2 visually support the thermal-escape opportunity offered by the Akçadağ, Darende and Yazıhan plateaus (1,200–1,800 m) around the Battalgazi plain (≈900 m). The elevation-belt synthesis (Table 5) quantifies this process, showing that in the period average more than half of production (53.9%) now takes place in the high-plateau belt.

This spatial shift has two fundamental driving forces. The first is the phenological advancement triggered by climate change; the roughly 2.4°C rise in mean annual temperatures between 1980 and 2020 advanced flowering, widening the exposure of the orchards on the basin floor to the late-frost window (Balcıoğlu et al., 2022; Avcı and Esen, 2019). The warming rendered rain-fed apricot growing economically feasible at the high elevations formerly cold; thus production "climbed upward" toward the ecologically safer plateaus. This process can be read as an agricultural example of the concept of "altitudinal migration", frequently discussed in mountain-area geography; but here what migrates is not the human being but the production activity itself. The second is the loss of agricultural character of the fertile alluvial lands in the Malatya Plain, and especially in the Battalgazi district, under rapid and unplanned urban-sprawl pressure (Dağ, 2021; Cengiz and Yılmaz, 2016; Görmüş et al., 2018). These two processes together have led the clustering to display a vectorial shift from the plain toward the plateau. In this respect the findings integrate the qualitative observations of Çağlıyan and Dağlı (2017) and Özüpekçe (2021) with quantitative concentration measures.

This pattern also coincides with the classic centre-periphery models of human geography: while the plain floor was historically in the position of the "centre" of production, it is losing this centrality under the dual pressure of urbanisation and climatic risk; and the high-plateau districts formerly regarded as "periphery" are coming to the fore as a new centre of gravity. However,

this relocation diverges from the classic centre-periphery models at one point: here the rise of the periphery stems not from the economic weakness of the centre but from the centre's loss of physical-climatic resilience. This may be regarded as an important case in agricultural geography in which climate change redraws the geography of production.

Another geographic finding of the study is that the districts in the eastern-southern valley corridor such as Doğanyol, Pütürge, Kale and Arapgir have a low but stable share throughout the period (12.7%) and showed growth by diverging from the other districts in the 2014 frost year. The deeply dissected, relatively enclosed topography of the Euphrates valley in these districts may point to a different microclimatic regime in terms of cold-air drainage and radiation-frost formation; however, since station-based meteorological data were not used in this study, this relationship is put forward as a hypothesis and left to future climate-geography studies.

The study has some limitations. The district-level concentration measures rest on the cross-section years 2004, 2014 and 2024 rather than an uninterrupted annual series; more frequently spaced data would increase the temporal resolution of the shift vectors. In addition, directly matching the station-based spatial distribution of frost events with district production records would, in future studies, strengthen the causal link. Nevertheless, the present findings offer a consistent and policy-meaningful picture regarding the direction and magnitude of the clustering dynamism.

A further limitation concerns spatial resolution. A more statistically robust characterisation of intra-provincial clustering would, in principle, use a larger number of spatial units than the 14 official districts analysed here for example, sub-district zones stratified by elevation belt and slope aspect, obtained by overlaying CORINE land-cover data to exclude non-agricultural mountainous, forested and bare-rock surfaces, and analysed on a fine-resolution grid (1 km × 1 km, or 50 m × 50 m for micro-topographic frost analysis) that could resolve cold-air drainage and frost pooling directly rather than inferring them at district scale. This regridding was judged to lie outside the scope of the present revision because TÜİK's Crop Production Statistics — the only continuous, verifiable, long-run data source for Malatya apricot output — report production exclusively at the province and district administrative levels; no official sub-district or grid-cell production series exists to populate such a framework, and constructing one would require independent estimation (for instance, from very-high-resolution orchard-canopy remote sensing) that constitutes a substantial project in its own right. We flag this explicitly as a priority direction for follow-up research. Similarly, and for the same data-availability reason, the panel used here closes at 2024. TÜİK's most recent provisional estimates indicate that Türkiye's apricot harvest fell by roughly 74% in 2025 relative to the record 2024 crop, with the sharpest losses again concentrated in Malatya following a severe nationwide frost event on 11 April 2025 (Hasdemir, 2025) — a development consistent with, and further reinforcing, the frost-driven volatility thesis argued throughout this study. District-level 2025 figures for Malatya's individual districts had not yet been finalised in TÜİK's official database at the time of this revision, so the 2025 season could not be integrated into the concentration indices (HHI, CR1, CR3) without compromising their internal consistency across the panel; it will be incorporated as an additional cross-section as soon as TÜİK's finalised district-level release becomes available.

Conclusion And Recommendations

This study analysed, holistically and within a geographic framework, the spatial distribution, growth momentum, volatility and clustering dynamism of apricot production among the 14 districts of Malatya over the 2004–2024 period. Three main conclusions were reached. First, the weak bond between intra-provincial production and planted area (r=0.40) proves that the source of volatility is not capacity but climate — especially late spring frosts. Second, and most originally, the intra-provincial clustering structure is not stationary: frost risk and urban-sprawl pressure shift the production centre of gravity from the Battalgazi plain toward the surrounding plateaus, with concentration indices rising in crisis years and then re-dispersing. Third, the elevation-belt synthesis shows that in the period average more than half of production (53.9%) now takes place in the high-plateau belt (Akçadağ, Darende, Hekimhan, Yazıhan, Kuluncak, Arguvan), while the plain floor (33.4%) and the eastern-southern valley corridor (12.7%) remain comparatively in the background.

In light of these results, recommendations for decision-makers can be summarized separately as follows:

Agricultural grants, seedling support and irrigation investments should be differentiated by elevation belts (basin floor, low plateau, high plateau) rather than by district boundaries. The dissemination of late-flowering varieties and frost-resistant rootstocks on the high-frost-risk valley floors, and the support of infrastructure suitable for rain-fed growing on the high plateaus, should be priorities.

In a system where production volatility is this high, it is critically important to increase the coverage and participation rate of state-supported agricultural insurance (TARSİM) at the district scale, especially in the high-frost-risk valley-floor districts. Designing crop-insurance products specific to frost events may prevent producers from abandoning their production sites in crisis years (Uçar and Engindeniz, 2019; Çukur and Saner, 2008).

Opening the Class I, II and III alluvial lands in Battalgazi and Yeşilyurt to construction creates an irreversible agricultural loss. These lands must be taken under protection with the status of "absolute agricultural land", and urban growth must be directed to non-agricultural areas.

The geographical-indication value of the Malatya apricot must be updated in the face of the intra-provincial spatial shift of production. The elevation- and district-based mapping of the production basin must be integrated into origin-control and traceability systems to protect the value of the brand.

The relative resilience shown in the 2014 frost year by the districts in the eastern-southern valley corridor (Doğanyol, Pütürge, Kale) makes it necessary to investigate the microclimatic characteristics of these districts with station-based meteorological observations

and, if appropriate, to consider them as an additional buffer basin for apricot growing.

In conclusion, the Malatya apricot cluster is not a stationary geographic phenomenon; it is a dynamic spatial system continuously reshaped by climate change and urbanisation. The regular monitoring of this dynamism at the district and elevation scale with geographic information systems and spatial-concentration measures offers an indispensable decision-support tool both for local rural development and for regional agricultural-geography planning. Future research may further strengthen the causality of the shift vectors by matching district production data with uninterrupted annual series and station-based frost records.

Declarations

Ethics Approval Certificate

Ethics Committee approval is not required for this study.

Funding Statement

This study was not funded by any institution/organisation.

Conflict of Interest

The authors do not declare any conflicts of interest.

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