Production and Export Performance of Afghan Saffron over the Past Decade

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ABSTRACT

Saffron (*Crocus sativus* L.), widely known as "red gold," is one of the most valuable agricultural commodities and plays a significant role in rural livelihoods, export earnings, and economic diversification in Afghanistan. The study examined the production and export performance of Afghan saffron, using secondary data on area, production, productivity, and exports from 2014–15 to 2023–24. To evaluate trends in production and exports, the Compound Annual Growth Rate (CAGR) and Ordinary Least Squares (OLS) methods were employed. The coefficient of variation (CV) and the Cuddy–Della Valle (CDV) instability index were used to assess instability. Additionally, Markov Chain Analysis was applied to examine trade direction. The results indicated that the cultivated area, production, and export value of Afghan saffron increased significantly at annual growth rates of 29.07, 22.59, and 23.78 per cent, respectively. In contrast, productivity declined at an annual rate of -5.02 per cent, which was statistically non-significant. These findings suggest that production growth was driven primarily by quantitative expansion, with no significant improvement in production efficiency. The highest fluctuation was observed in productivity, followed by area, production, and export value. Saudi Arabia was recognized as the most stable market for Afghan saffron, followed by India. Ultimately, the results underscore the importance of focusing on increasing productivity, enhancing quality, and expanding export markets to achieve sustainable growth.

INTRODUCTION

Saffron (*Crocus sativus* L.) is one of the most popular traditional plants and the world's most expensive spice. As one of the world's most valuable agricultural products, saffron plays a significant role in generating employment, increasing farmers' incomes, and developing exports in producing countries. Global saffron production in 2023 was estimated at 418 tons cultivated over 121,338 hectares (Tosan et al., 2024). This crop is predominantly cultivated in Iran, which accounts for over 90 per cent of global production, followed by India, Afghanistan, and countries of the Mediterranean region (Pedro de Padua et al., 2023). Saffron is widely recognized as a traditional plant and is primarily used as a food additive in Asian and European countries (Seyedi-Sahebari et al., 2024). Owing to its distinctive color, flavor, and

aroma, saffron is considered a unique food source and one of the most expensive spices worldwide (Tsimidou, 2023). Due to labor-intensive manual harvesting and low production volumes, saffron is often referred to as "red gold" (Golpour-Hamedani et al., 2024). Scientific evidence also demonstrates the positive effects of saffron in alleviating anxiety, depression, and memory- and learning-related disorders such as Alzheimer's disease (Marzabadi et al., 2022; Sanaie et al., 2023). Consequently, global demand for saffron has increased due to its applications as a dietary supplement, medicinal product, and cosmetic ingredient (Cardone et al., 2020; Yaqubi et al., 2024). In 2023, global saffron trade reached USD 66 million, a 4.16 per cent increase from 2022, when total trade amounted to USD 55 million. In the same year, the major saffron exporters were Iran (43.40 per cent global share, export value USD 15 million), Spain (23.30 per cent share, USD 62.1 million), and Afghanistan (21.40 per cent share, USD 56.9 million), respectively (OEC, 2025). In Afghanistan, favorable climatic conditions, relatively low labor costs, and the high value addition associated with saffron production have positioned it as a viable alternative to traditional and illicit crops such as poppy and hashish, attracting increasing attention from policymakers, farmers, and exporters (Nabizada, 2010; Minoia & Pain, 2016).

In 2023, saffron cultivation in Afghanistan was mainly concentrated in Herat Province, producing 22,240 kg from 7,952 hectares, and to a lesser extent in Kandahar (652 kg from 74 ha), Balkh (60 kg from 120 ha), Farah (28 kg from 7 ha), and Faryab (2 kg from 1 ha). This highlights saffron's strategic importance within Afghanistan's agricultural and commercial structure. Despite significant expansion in cultivated areas and increases in production and exports over the past decade, the sustainability of this growth remains uncertain. Production gains have largely resulted from the expansion of cultivated land, while productivity has stagnated or declined in certain years (Hosainy, 2024). This indicates that sectoral development has been predominantly quantitative, with limited emphasis on improving productivity, quality, farm management, and adoption of modern technologies (Azimi et al., 2020). Continued reliance on area expansion alone may reduce production efficiency and weaken the long-term competitiveness of Afghan saffron in global markets. Moreover, fluctuations in cultivated area, production, productivity, and exports raise concerns about sectoral stability and long-term sustainability. Productivity constraints related to crop quality, water management, farm practices, post-harvest handling, and climatic variability continue to affect farmer incomes and export competitiveness.

Although Afghan saffron exports have recorded substantial growth in export value and key markets such as Saudi Arabia and India have emerged as major destinations, heavy concentration in a limited number of markets and fluctuating market shares elsewhere increase vulnerability to price volatility, global competition, and quality inconsistency. Understanding export market dynamics and assessing their stability are therefore, crucial for formulating effective trade policies and ensuring sustainable export development. Accordingly, the present study aims to comprehensively analyze trade direction, growth trends, and instability in area, production, productivity, and exports of Afghan saffron during

the period 2014–2023. The Compound Annual Growth Rate (CAGR) was employed to evaluate trends. At the same time, the Coefficient of Variation (CV) and the Cuddy–Della Valle (CDV) instability index were used to measure instability in the selected indicators. In addition, changes in export market shares and their sustainability were examined using Markov Chain Analysis. The findings of this study provide a basis for identifying strengths and weaknesses in the saffron sector and for proposing policy measures to enhance productivity, improve quality, and strengthen Afghanistan's position in international markets. Based on these considerations, the specific objectives of the study are to:

- Evaluate trends and performance of saffron production in Afghanistan during the study period;
- Examine the stability or instability of export market shares and identify the most stable markets for Afghan saffron; and
- Propose appropriate measures to improve saffron productivity and export performance in Afghanistan.

A growing body of literature has examined growth trends, instability, and trade direction of saffron and other agricultural commodities using tools such as CAGR, CV, CDV indices, and Markov Chain Analysis. Noori & Moulavizada (2018) analyzed the production and export performance of saffron in Afghanistan and reported increasing trends in cultivated area and production, identifying the United Arab Emirates as the most stable export market, followed by India. Esar et al. (2024) examined the economic potential of Afghan saffron using an exponential growth model for the period 1991–92 to 2021–22. They reported significant growth in area (29.61 per cent), production (29.06 per cent), and productivity (0.42 per cent). Mushair et al. (2020) analyzed export performance and trade direction of fresh and dried grapes from Afghanistan and identified Pakistan as the most stable market. Similarly, Alizadah et al. (2024) evaluated production and export performance of fresh and dried figs from Afghanistan and India, reporting higher instability in Afghanistan and identifying India as the most stable market for Afghan figs.

MATERIALS AND METHODS

This research used data analysis of saffron cultivation areas, production, productivity, and exports over the past decade (2014-2023). The data were obtained from various sources, including the Statistical Yearbook of Afghanistan, the website of the National Statistical Information Authority (NSIA), and the Observatory of Economic Complexity (OEC) in Afghanistan.

Compound Annual Growth Rate (CAGR)

To analyze trends and evaluate the growth rates of saffron cultivation area, production, productivity, and export value in Afghanistan, the Compound Annual Growth Rate (CAGR) was employed. The exponential growth function of the following form was used to calculate the CAGR of Afghan saffron data (Nithin, 2016; Champaneri & Patel, 2022; Esar et al., 2024):

$$Y_t = ab^t \times u_t \qquad (1)$$

Where,

Y_t = area, production, productivity, and export value of saffron in year t,

t = time variable (year),

u_t = disturbance term,

'a ' and 'b' are regression parameters to be estimated.

Equation (1), after taking the logarithm, is transformed into the following linear form:

$$lnY_t = lna + t\,lnb + lnu_t \qquad (2)$$

Equation (2) was estimated using the Ordinary Least Squares (OLS) method, and after estimating the parameter b, the annual compound growth rate (g) was calculated according to the following relationship:

$$(3)g = (anti\ log\ of\ b - 1) \times 100$$

Where,

g = Compound annual growth rate in percentage form,

b = anti-log of b.

Instability analysis

Instability is considered an important decision criterion in agricultural production, where high growth and low volatility are preferred. Instability in agricultural products is usually influenced by various factors such as production technology, improved variety, nature, economy, climate sensitivity, and access to inputs (Rana et al., 2021). The coefficient of variation (CV) is the dispersion of the standard deviation around the mean and was employed as a measure of variation in the area, production, productivity, and export of saffron from Afghanistan. The CV, or index of instability, was calculated using the following formula:

$$CV(\text{per cent}) = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

Further, the instability in area, production, productivity, and export of Afghan saffron was examined in related terms by the Cuddy Della Valle index (Cuddy & Della Valle, 1978), which was employed by many researchers (Shilpa & Sharma, 2021; Bhatia et al., 2021) as a measure of variability in time series data. The coefficients of variation overstate the degree of instability in time series data. In contrast, the Cuddy-Della Valle index corrects the CV, shows the precise direction of the instability, and detrends the annual rate.

$$\text{Instability index} = CV \times \sqrt{(1 - R^2)}$$

Where,

CV = simple coefficient of variation (per cent) and

R^2 = coefficient of determination from time trend regression adjusted for degrees of freedom.

Markov Chain Analysis

To analyze trade direction and examine the dynamics of Afghan saffron export patterns, a Markov Chain Analysis was employed, as adopted by several researchers, including Kumari & Rede (2024), Mohammadi & Mushair (2022), and Alizadah et al. (2024). This method uses export data covering ten years (2014–2023) to examine temporal structural changes in which the value of a variable in each period depends on its value in the preceding period.

Within this framework, a transition probability matrix 'P' has been developed, whose elements P_{ij} represent the probability of export transitions from country 'i' to country 'j' in the next period. The diagonal elements of matrix P_{ij} represent the probability of maintaining market share and the level of loyalty of the importing country over time.

The main relationship of the model is defined as follows:

$$E_{jt} = \sum_{i=1}^{n} [E_{it-1}] \, P_{ij} + e_{jt}$$

E_{jt} = Afghan saffron exports to country 'j' in year 't',

E_{it-1} = Country 'i' exports in the previous year,

P_{ij} = probability of export transfer from country 'i' to country 'j',

e_{jt} = random error limit,

n = number of importing countries.

The transition probability matrix must satisfy the following conditions:

$$\sum_{i=1}^{n} P_{ij} = 1 \quad \text{and} \quad 0 \leq P_{ij} \leq 1$$

Min, OP*+Ie

Subject to:

    XP* + V = Y
    GP = 1
    P ≥ 0
Where,

O = zero vector,

P = vector containing probabilities P_{ij},

I = unit vectors,

e = absolute error vector,

Y = Export vector to each country,

X = a block diagonal matrix of values with export delays,

V = error vector,

G = Grouping matrix for summing row elements 'P' until reaching one.

After calculating the transition probability matrix, the expected export share is calculated using the following expanded formula:

$$B_t = B_0 * T$$
$$B_{t+i} = B_{t+i-1} * T$$

Where,

B_0 = Export amount in base year,

B_{t+i} = Export amount in the next year (prediction),

T = Estimated transition probability matrix.

The values in each transition probability matrix have a specific interpretation: The diagonal elements represent the probability of maintaining the previous year's export share; the values in each column indicate the probability of gaining share from other countries; and the values in each row express the probability of losing export share to other countries.

FINDINGS

Growth Rates of Area, Production, Productivity, and Exports of Afghan Saffron

The growth rates and significance levels of area, production, productivity, and export value of Afghan saffron during the study period were analyzed and presented in Table 1. The results showed positive, statistically significant growth across several indicators. The cultivated area increased at an annual rate of 29.07 per cent, averaging 5,602.94 hectares. Similarly, production grew by 22.59 per cent per year, averaging 13,426.87 kg. The export value also recorded statistically significant and favorable annual growth of 23.78 per cent, with an average value of USD 28.86 million. In contrast, productivity showed a negative CAGR of −5.02 per cent, with an average yield of 2.70 kg/ha, and the change was not statistically significant, indicating that yield variations were not meaningful over the study period.

Table 1. *Compound annual growth rates in area, production, productivity, and export of Afghan saffron during 2014-2023.*

Indicators	CAGR (Per cent)	Average
Area(ha)	29.07[*]	5602.94
Production(kg)	22.59[*]	13426.87
Productivity(Kg/ha)	-5.02[NS]	2.70
Export value(million USD)	23.78[*]	28.86

* Significant at 1 per cent levels. NS: Non-significant.
Source: Author's calculation.

Instability in Area, Production, Productivity, and Export of Afghan Saffron

The coefficient of variation and CDV instability index for the area, production, productivity, and export value of Afghan saffron were calculated and presented in Table 2. During the

study period, in terms of CV, the highest variability was recorded for production (56.12 per cent), followed by export value (54.86 per cent) and cultivated area (54.01 per cent), respectively. At the same time, productivity showed comparatively lower instability (34.02 per cent). In terms of the CDV index, all indicators showed moderate instability, with the highest instability in productivity (30.39 per cent), followed by area (26.00 per cent), production (24.89 per cent), and export value (21.15 per cent). Indicating relatively more stability in the export performance of saffron compared to other indicators.

Table 2: *Instability in area, production, productivity, and export of Afghan saffron during 2014 - 2023*

Indicators	CV (per cent)	CDV (per cent)
Area	54.01	26.00
Production	56.12	24.89
Productivity	34.٠٢	30.3٩
Export value	54.8٦	21.1٥

Source: Author's calculation

Trade direction of Afghan Saffron

Afghan saffron has been exported mainly to Saudi Arabia and India over the past decade. Smaller quantities have also been exported to Spain, Germany, and other minor importing countries grouped under the category "other countries" (Table 3). Saudi Arabia, with a retention probability of 91.51 per cent, was identified as the most stable market among the major importers of Afghan saffron. Of the remaining 8.49 per cent of Saudi Arabia's market share, 2.03 per cent was allocated to Spain, 2.23 per cent to the United States, 3.19 per cent to the United Arab Emirates, and 1.04 per cent to Kuwait. India has also been a relatively stable market for Afghan saffron, with a retention probability of 79.42 per cent. Of India's remaining market share, 9.89 per cent shifted to Saudi Arabia, 1.54 per cent to the United States, 0.44 per cent to the United Arab Emirates, 0.30 per cent to Germany, 0.02 per cent to Kuwait, and 8.39 per cent to other importing countries.

In contrast, secondary markets exhibited lower retention probabilities. Spain retained 39.69 per cent of its import share, while Germany retained only 5.52 per cent, indicating comparatively lower stability. Markets such as the United States, the United Arab Emirates, and Kuwait showed no retention of their previous shares, with exports shifting to other destinations over time.

Table 3. *Transitional probability matrix of the export of Afghan saffron*

countries	India	Saudi Arabia	Spain	US	UAE	Germany	Kuwait	Others
India	0.7942	0.0989	0.0000	0.0154	0.0044	0.0030	0.0002	0.0839
Saudi Arabia	0.0000	0.9151	0.0203	0.0223	0.0319	0.0000	0.0104	0.0000
Spain	0.6031	0.0000	0.3969	0.0000	0.0000	0.0000	0.0000	0.0000

US	0.1142	0.0000	0.0716	**0.0000**	0.0000	0.0648	0.0000	0.7494
UAE	0.0000	0.4482	0.5518	0.0000	**0.0000**	0.0000	0.0000	0.0000
Germany	0.0000	0.0000	0.4410	0.2957	0.2081	**0.0552**	0.0000	0.0000
Kuwait	0.0000	0.4388	0.0000	0.0000	0.0000	0.5612	**0.0000**	0.0000
Others	0.8997	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	**0.1003**

Source: Author's calculation

DISCUSSION

The findings indicated that the Afghan saffron sector experienced substantial growth during the study period (2014-2023). The cultivated area expanded at a compound annual growth rate of 29.07 per cent. In comparison, total production increased by 22.59 per cent per year, and export value grew by 23.78 per cent annually, reflecting rising global demand for Afghan saffron. This rapid development has been largely driven by area expansion and strong export performance. Saffron is a vital source of income for Afghan farmers, particularly the poor, due to its high economic returns, a short two-month growth cycle, low labor requirements, and minimal irrigation needs, with up to 80 per cent of cultivation carried out by women (Esar et al., 2024). Favorable climate, low labor costs, and high market value make it a viable alternative to traditional and illicit crops such as poppy and hashish (Nabizada, 2010; Minoia & Pain, 2016; World Bank, 2015). Beyond its economic importance, saffron has attracted scientific interest for its antioxidant, anti-inflammatory, anticancer, and metabolic health benefits, highlighting its dual potential as a high-value and functional crop (Tosan et al., 2024).

Moreover, the present study supports the work of Esar et al. (2024), who reported that the growth rates of area, production, and productivity of Afghan saffron significantly increased by 29.61, 29.06, and 0.42 per cent annually, respectively. Additionally, the returns per hectare of Afghan saffron were compared with those of other crops such as wheat, rice, corn, and barley, and saffron was found to yield the highest returns. The export of Afghan saffron also increased annually, providing farmers with more income opportunities.

Despite these positive developments, productivity declined slightly, but not significantly, by 5.02 per cent, averaging 2.70 kg/ha. This indicates that the growth in total production was largely driven by the expansion of cultivated area rather than improvements in yield, reflecting limited progress in cultivation practices and agronomic efficiency. This observation aligns with previous studies; for instance, Hosainy (2024) reported inefficient use of key production inputs such as land, labor, and water among saffron farmers. Similarly, Nawab et al. (2022) highlighted the need to strengthen farmers' capacity through training programs, field demonstrations, exposure visits, and improved access to credit facilities, thereby helping smallholders enhance production efficiency. Furthermore, Azimi et al. (2020) noted that the development of Afghanistan's saffron sector has been largely quantitative, with insufficient focus on productivity improvements, quality enhancement, farm management, and adoption of modern technologies.

The instability analysis further complements these findings. In terms of the coefficient of variation (CV), production (56.12 per cent), export value (54.86 per cent), and area (54.01 per cent) displayed high variability, while productivity showed comparatively lower variability (34.02 per cent). The CDV index indicated moderate instability across all indicators, with productivity exhibiting the highest instability (30.39 per cent), followed by area (26.00 per cent), production (24.89 per cent), and export value (21.15 per cent), respectively. These results indicate that, although export performance appears relatively stable, production and cultivated area remain subject to considerable fluctuations. The relatively high instability in productivity may reflect vulnerability to climatic variability, inconsistent corm quality, inadequate irrigation practices, and limited extension support. Such structural challenges could constrain long-term productivity growth and reduce the sector's resilience to external shocks.

The transitional probability analysis of saffron exports revealed that Saudi Arabia and India are the most stable markets, retaining 91.51 and 79.42 per cent of their previous import shares, respectively. These results are consistent with those of Noori & Moulavizada (2018). In contrast, secondary markets such as Spain and Germany showed lower retention (39.69% and 5.52%), while the United States, UAE, and Kuwait were unable to maintain consistent import shares over time. This pattern highlights the importance of stable anchor markets in sustaining export performance, while also signaling high volatility in emerging or minor markets.

The study has several limitations in the production and export of saffron. The analysis relies on secondary data, which may be subject to reporting errors or inconsistencies in government and trade statistics. The study period covers only 2014–2023, which may not fully capture longer-term trends or earlier structural changes in Afghanistan's saffron sector. The productivity assessment does not consider regional variations, soil conditions, or irrigation practices, all of which may significantly influence yield performance. Finally, the export market analysis is based on aggregate country-level data. It does not account for differences in product quality, packaging, branding, or certification, which may affect export competitiveness and market stability.

Based on these findings, future research should focus on examining agronomic factors, including corm quality, soil management, and irrigation practices, to identify strategies for improving productivity. Investigating spatial variations in saffron cultivation and performance to inform targeted interventions. Analyzing emerging international markets and trade policies to reduce over-reliance on Saudi Arabia and India. Exploring the impact of post-harvest handling, branding, and quality certification on export stability and market competitiveness (Habibzadeh, 2024). Assess the potential impact of climate change, policy shifts, or global price volatility on future growth and stability.

This study analyzed the growth, instability, and trade direction of Afghan saffron over the past decade. The findings showed significant expansion, with cultivated area, production, and export value increasing annually by 29.07, 22.59, and 23.78 per cent, respectively. This

growth highlights the rising importance of saffron as a high-value crop and export commodity in Afghanistan. However, productivity showed a slight, non-significant decline (−5.02 per cent), indicating that the increase in production was mainly driven by the expansion of cultivated area rather than by improvements in yield. The instability analysis revealed moderate fluctuations across key indicators, with higher variability in production and cultivated area, while export performance remained comparatively more stable. The trade direction analysis also indicated that Saudi Arabia and India are the most stable markets for Afghan saffron exports, whereas other markets showed greater volatility. Overall, improving productivity, strengthening agronomic practices, and diversifying export markets will be essential to sustain the long-term growth and competitiveness of Afghanistan's saffron sector.

AUTHORS CONTRIBUTIONS

Mohammad Hussain Alizadah investigated and analyzed the data and wrote the manuscript with input from all authors. Sayed Abull Hassan Hosainy conceptualized and supervised the study. Sunatullah Ghafori reviewed and approved the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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