ASSESSMENT OF HUNGARIAN PLUM PRODUCTION COMPETITIVENESS ON THE SINGLE MARKET OF THE EU

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A B S T R A C T

The research assesses the competitiveness of Hungarian plum production in the EU single market between 2004 and 2020. The plum production area remained relatively stable at 7,900 hectares during the observed period, whereas the yield per hectare fluctuated from 3.6 to 9.8 tones per hectare, influencing the annual plum harvest output from 27,000 to 70,000 tones per year. Hungary has predominantly been an export-oriented country with regard to in terms of plum production. This was supported by a positive RCA index measured during the investigated period. The most significant decrease in competitiveness was established at the end of the investigated period in 2020. According to the regression analysis results, harvested production was a highly significant positive predictor of RCA (standardized $\beta = 0.81$, $p < 0.001$). In order to preserve the competitive advantage of Hungarian plum production, it will be necessary to boost yield stability and add value to primary agricultural production.

Introduction

V4 (containing Czech Republic, Hungary, Poland and Slovakia) countries became members of the EU in 2004 along with six other countries. A study conducted by Svatoš and Smutka (2012) proved that three of them increased their agricultural production and export volumes. Hungarian agriculture faced challenges and structural decline. This unfavourable development was due to Hungary's focus on low-value commodities. Such a narrow approach and territorial focus of the export policy made Hungary

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vulnerable to market shocks. The results emphasized the need for diversification, value-added production, and alignment with the EU market to improve long-term performance. These needs can be fulfilled through the implementation of innovative technology, structural reforms, and improved market adaptability (Cuaresma et al. 2008; Böwer and Turrini, 2010).

Competitiveness of agricultural sector research has undergone a broad change in the past decades. Policy reforms alone are not sufficient unless they forget to address the small and medium-sized or otherwise disadvantaged farmers. In case of EU countries, it further requires adapting measures ensuring fair distribution of CAP finances (Gorton, M., Davidova, S., Ratinger, T., 2000; Viegas et al., 2023). Apart from adapting the political measures it is important to implement modern technologies in small and medium-sized farms as well. Digitalization can help to enhance resilience, sustainability, and global competitiveness too (Tomashuk et al., 2025).

High competitiveness of the agricultural sector does not automatically mean that it is sustainable from a long-term point of view, nor that it excels in productivity. Serbia is one of those countries with higher comparative advantages, but this is mostly based on low prices and comparatively high yields per hectare. Moreover, from the social and economic side, there is low labor productivity and outdated technology included which leads to lower added value in the chain. To improve this situation local economists recommend aligning national agricultural policy to the EU's CAP and investments in innovation and processing to ensure future competitiveness. Similar observations were seen in other Balkan countries as well as other less developed countries outside of the European continent (Ahmed et al., 2022; Chiarella et al., 2023; Dimitrijević et al., 2025).

The inconsistency with the international quality standards and low domestic processing confirmed the decreasing export and agricultural competitiveness in China. Over two decades, the competitiveness and comparative advantage (RCA) indices have proved the decreasing role of agriculture in global trade. The results have shown that to boost production, it is necessary to reform the national policies and align them with global policies to improve market access. Along with the policy reforms, it is necessary to improve the sector through investments in innovative technologies and structural reforms to reinforce the global trade position (Long, 2021; Dubey et al., 2022; Tang et al., 2024).

Similar results were observed in Malaysian agricultural production. Using a similar methodology, economists found out that only 1/3 of the commodities have a higher comparative advantage with palm oil as their top commodity. The reasons for negative development were prices, GDP per capita and reliance on exporting mainly raw materials with lower value added for long-term sustainability. Among the key factors that can improve the situation are stable prices on the market, a more skilled labor force, and capital investments in the sector to promote the processing and increase the value added (Siew-Ling Liew et al., 2021; Saxena et al., 2023).

Targeted and updated policy reforms along with the agility on the market, are important in enhancing competitiveness. Similar problems are observed globally, but are visible especially in India using indexes such as Revealed Comparative Advantage (RCA). For the past 30 years their agricultural production and export have increased in absolute values but their share of the global market is decreasing and indicating the loss of competitiveness. It provides another signal that quality is gaining over quantity, as the main challenges for Indian producers are not only higher transaction costs after COVID-19 but also lower phytosanitary standards. Current trade conditions and government contracts lead to higher exports to countries such as Banglades, Iran and Thailand (Kumar, 2022).

Positive impacts of changes in the policy can be observed in Romania. After entering the EU, Romania, as other new member states after 2004, was eligible for the Single Area Payment Scheme (SAPS). This supranational support led to stabilizing income and prices, especially in the case of the small and medium-sized farmers. Nevertheless, it should be emphasized that with positive impact on competitiveness came excessive bureaucracy and limited access to other financial sources. Furthermore, the economists claimed that long-term competitiveness requires policy reforms focused on innovation, market development, and structural modernization. Furthermore, the structure of ownership highly influences the distribution of subsidies (Cugleșan, 2021; Barral and Detang-Dessendre, 2023; Ionașcu, 2024; Pokrivcak et al., 2025).

On the other hand, critical voices are emerging that relying on the Balassa’s RCA analysis is both overestimated and limited in scope, and therefore, alternative aspects, such as circular economy principles and technological/digital innovations, should be brought into consideration in boosting competitiveness. Countries with high raw cereal exports (like Romania and Hungary) often lack competitiveness in processed foods, whereas countries with cereal trade deficits (like Italy and Ireland) excel in value-added exports. This suggests inefficiencies in resource management and underscores the need to trace added value along the entire agri-food chain. We can see cooperative networks in Asia or Europe but these seem to be more regionally embedded. More researchers call for a global agenda to address the emerging challenges. Similarly, Ukrainian researchers confirm that an integrated approach is necessary to enhance the competitiveness of agricultural enterprises. Amplifying the production can be achieved through innovative technologies, modern equipment, and high professional standards, all aligned with European quality benchmarks. On the other hand, the relationship between the producers and innovators is the main weakness (Istudor, et al., 2022; Mahiiovych and Zelisko, 2022; Rodríguez-Mañay et al., 2024).

Competitiveness of the agricultural sector depends on several environmental, economic and social factors that enhance the effectiveness of the sector. Among the most important we can count innovation in the sector, investments into infrastructure, education in the country and lastly the public support. Innovation factor is connected to use of digital technologies such as drones or other types of automated systems focused on increasing productivity and sustainability. But even the increased role of the government does not guarantee the resiliency of the sector. This can be achieved by activities focused on rural development and applying up to date environmental practices. There have been several studies carried out and all of them resulted in call for a comprehensive, multi-level approach combining public, social, economic and environmental efforts leading to increased competitiveness of the sector (Borisov et al., 2021; Abad-Segura et al., 2024; Rizzo et al., 2024; Kuandykova et al., 2025).

Based on the previously conducted research, the article focuses on a specific agricultural commodity (plum) in a selected EU country (Hungary). Investigation conducted by the statistical models seeks the answer what are actually the key production factors that determine revealed comparative advantage of Hungarian plum production on the Single market of the EU.

Materials and methods

The research conducts an investigation of Hungary's plum production and trade competitiveness between 2004 and 2020. It is a period beginning with Hungary's accession to the European Union. The time period was chosen for an assessment of competitiveness within the EU Single Market under relatively consistent policy conditions. Investigating the within this time series major disruptions after that date were avoided (such as Brexit and COVID-19). The data investigated within the article corresponds to annual observations within a 17-year period.

Following data sources were used for obtaining data for further analysis:

- Eurostat,
- Crop production under standard humidity,
- EU external trade database,
- Hungarian Central Statistical Office – national series on orchard area, fruit yields and gross production, cross-checked against Eurostat for consistency.

Table 1. Variables used for calculations

Variable	Unit	Identification
Orchard area (A)	Ha	Land under plum trees
Harvested production (P)	t	Total fresh plum output
Yield per ha (Y)	kg ha^{-1} (or t ha^{-1})	Productivity indicator
Exports (X)	€ 000	Trade supply to EU and world markets
Imports (M)	€ 000	Foreign supply to the Hungarian market

Source: prepared by authors

All monetary data are in current EUR. Physical quantities represent metric units (ha, kg, t).

Basic analysis of all variables has been provided by the descriptive statistics when each variable was observed for the observed period of time (N=17). Measures of central tendency, dispersion and variance were identified.

In order to identify competitive advantage of the country we used the concept of Revealed Comparative Advantage first introduced by Liesner (1958) and further improved by Balassa (1965). In the common years, there were significant modifications to the original competitiveness index introduced by Balassa (1965) with different approaches (Vollrath, 1991; Laursen, 1998; Yu et al., 2009). The competitiveness index introduced for the first time by T. L. Vollrath was applied in calculations based on its advantage of reflecting imports, normalized outcome and symmetric. Following this approach three formulas were adapted accordingly:

$$RXA_{i,a} = \ln\left(\frac{\frac{X_{ia}}{X_{i,total}}}{\frac{X_{ra}}{X_{r,total}}}\right) \quad (1)$$

Where:

i Hungary

a Product (fresh plums)

r EU-27

$X_{i,a}$ Hungary's plum exports

$X_{i,total}$ Hungary's total exports

$X_{r,a}$ EU plum exports

$X_{r,total}$ EU total exports

$$RMA_{i,a} = \ln\left(\frac{\frac{M_{ia}}{M_{i,total}}}{\frac{M_{ra}}{M_{r,total}}}\right) \quad (2)$$

Where:

$M_{i,a}$ Hungary's plum imports

$M_{i,total}$ Hungary's total imports

$M_{ri,a}$ EU plum imports

$M_{r,total}$ EU total imports

$$RCA_{i,a} = \ln(RXA_{i,a}) - \ln(RMA_{i,a}) \quad (3)$$

Where:

$RXA_{i,a}$ Relative export advantage

$RMA_{i,a}$ Relative import advantage

$RCA_{i,a}$ Revealed comparative advantage

RCA > 0 represents comparative advantage in plum production of Hungary.

In order to quantify relationships between production, factors observed within the previously conducted research and the revealed calculated advantage a multiple linear regression model was deployed:

$$RCA_t = \beta_0 + \beta_1 P_t + \beta_2 A_t + \varepsilon_t \quad (5)$$

Where:

RCA_t	Revealed comparative advantage in year t
P_t	Harvested production
A_t	Orchard area
β_0	Intercept
β_1, β_2	Slope coefficients
ε_t	OLS residual

Based on the regression analysis, a residual autocorrelation was conducted using the Durbin-Watson test:

$$\mathrm{DW} = \frac{\sum_{t'2}^{T}(e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2} \quad (6)$$

Where:

E_t	Regression residual
T	Sample size
DW	Durbin-Watson static

Based on data processed and calculations conducted the two hypotheses were set as the primary aim of the article mentioned within the introduction part:

H1: There is a positive relation between harvested production and the RCA of Hungarian plum production.

H2: Orchard area does significantly affect RCA index of Hungarian plum production.

Results and Discussion

Characteristics of plum production in Hungary between years 2004 and 2020

The statistical data provide a comprehensive view of the development of plum cultivation in the period under review, analyzing three key indicators: production in tons, orchard area in hectares, and yield in kilograms per hectare. The following text interprets the minimum and maximum values, quartiles, averages, and variance, including standard deviation.

Table 2. Descriptive statistics of production (thsd. kg), area (thsd. hectare) and yield (thsd. kg/hectare)

Statistic	Production	Area	Yield
Number of observations	17	17	17
Minimum	27.040	7.060	3.607
Maximum	70.850	9.000	9.772
1st quartile	43.270	7.540	5.453
Median	46.020	7.920	5.960
3rd quartile	51.490	8.280	6.635
Mean	47.428	7.933	5.989
Variance (n)	134.635	0.350	2.217
Standard deviation (n)	11.603	0.591	1.489

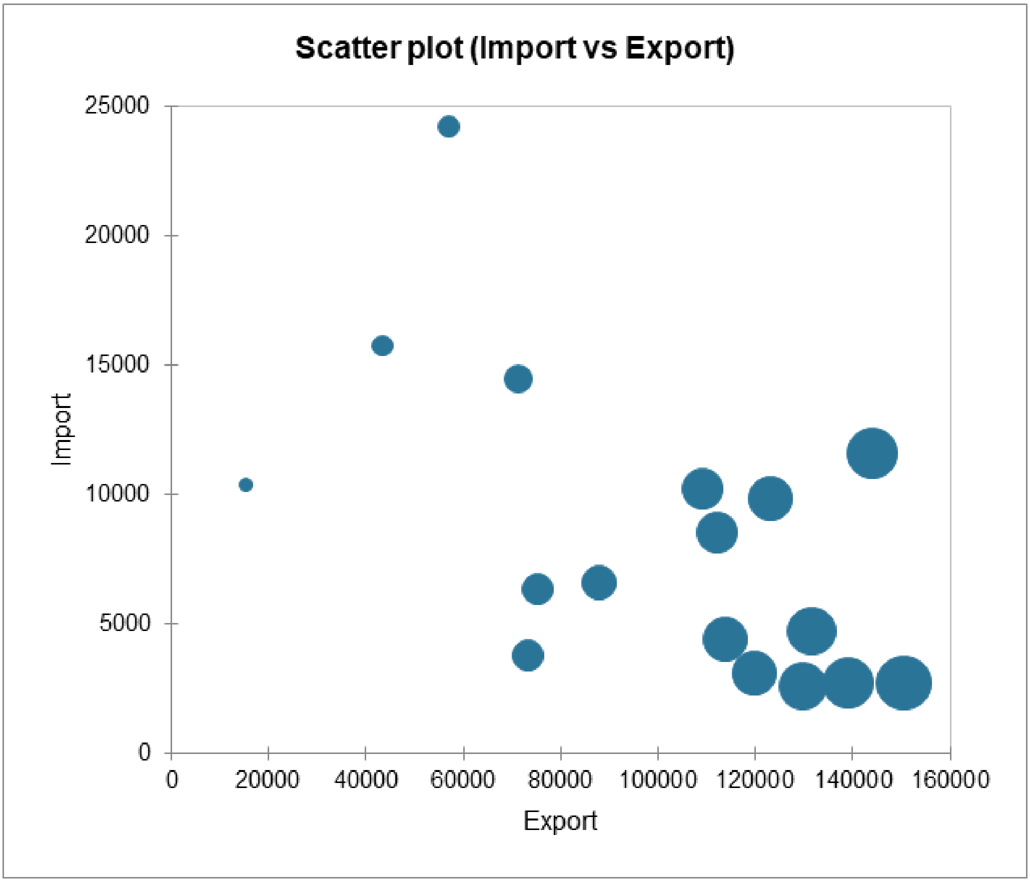
Source: Authors' calculations based on Eurostat database (ds-045409)

Plum production ranged from 27,040 tonnes (lowest) to 70,850 tonnes (highest). This significant difference indicates high interannual variability, probably caused by climatic conditions, diseases or interventions in orchard areas. The area of plum orchards fluctuated between 7,060 ha and 9,000 ha, which indicates a relatively stable area, without dramatic fluctuations. The yield per hectare reached only 3,607 kg/ha in the lowest year, while in the best year it reached 9,772 kg/ha. This variability indicates the influence of cultivation intensity, technology and climatic factors on production efficiency. The quartile distribution of the data suggests that most years are concentrated in the production range of 43,000 to 51,000 tonnes and yields between 5,400 and 6,600 kg/ha, with extreme fluctuations being the exception rather than the rule.

The average annual production was 47,428 tonnes, which is slightly above the median, indicating that extremely high values in some years increased the overall average. The average area of orchards was 7,933 ha, confirming the stability of the area. The average yield was 5,989 kg/ha, which is only slightly above the median. This indicates a uniform distribution of the data and no significant deviations.

The standard deviation of production at 11,603 tonnes indicates significant year-to-year fluctuations, probably caused by external factors such as weather or pest occurrence, while the standard deviation of orchard area of only 0.591 ha confirms their almost constant size, and the yield deviation of 1,489 kg/ha indicates slight to moderate variability, mainly influenced by growing conditions and technology.

Figure 1. Import vs. export relation reflecting the trade balance value between the 2004 and 2020



Source: Authors' calculations based on Eurostat database (ds-045409)

Hungary is an export-oriented market economy with a strong emphasis on foreign trade. Its foreign trade is territorially focused primarily on EU member states, where the customs union ensures the free movement of goods and services. The following Figure 1 shows the relationship between the values of Hungarian plum exports and imports during the observed period from 2004 to 2020. In general, export values are higher than import values. In several years, however, imports exceeded exports, which may indicate an increased demand for imported plums. It can be concluded that Hungary is more of an exporter than an importer of plums. The volume of exports increased between 2004 and 2020, while imports remained relatively low.

Influence of area and harvested production on the revealed comparative advantage of the Hungarian plum production

In the following section, we compare the revealed export advantage, revealed market advantage, and revealed comparative advantage of Hungarian plum production between the years examined (2004-2020).

Table 3. Comparison of revealed export advantage, revealed market advantage and revealed comparative advantage of the Hungarian plum production between 2004 and 2020

Year	Ln RXA	Ln RMA	RCA
2004	1.93	-1,69	3.62
2005	0.81	-0,38	1.20
2006	2.32	-1,53	3.84
2007	1.36	-0,01	1.37
2008	1.98	-0,98	2.96
2009	2.19	-2,07	4.26
2010	2.22	-1,98	4.21
2011	1.69	-1,65	3.33
2012	2.21	-1,85	4.06
2013	2.00	-1,19	3.19
2014	2.06	-0,60	2.67
2015	1.74	-0,94	2.68
2016	2.08	-0,64	2.72
2017	1.69	-0,47	2.15
2018	1.87	-0,78	2.66
2019	1.96	-0,17	2.13
2020	0.45	-0,64	1.10

Source: Authors' calculations based on Eurostat database (ds-045409)

The revealed export advantage indicator varied during the period under review, but in most years RXA is above 1, which means that Hungary had a relative advantage in plum exports. The highest value was observed in the year 2006 (2.32)... The RMA indicator is below 1 in all observed years, which means that Hungary primarily focused on exports and less on plum imports. The latter RCA indicator was significantly above 1 in almost all years, meaning that Hungary had a strong comparative advantage in plum exports in the long term.

The highest value was in 2009 (4.26) and 2010 (4.21), the strongest years for plum exports. The last RCA indicator was significantly above 1 in almost all years, which means that Hungary has had a strong comparative advantage in plum exports in the long term. The highest value was in 2009 (4.26) and 2010 (4.21), the strongest years for plum exports. In 2020, the RCA dropped sharply to 1.10, indicating that Hungary has lost its dominance in this sector.

The above values show that Hungary was a strong exporter of plums in period 2009-2019, while imports were minimal. The situation started to change in 2017, when imports started to grow, and exports decreased. In 2020, a turning point occurred, when Hungary lost its export and comparative advantage. This situation occurred due to a combination of several factors. In particular, weather problems are the main reason for the decrease in trade volume and imports of fresh plums. Trade prices move along with the availability of fruit. Shortages result in higher prices. Plums must remain affordable, otherwise consumers will not buy them. Lower availability and high prices increase opportunities for alternative suppliers, especially in neighboring countries.

Comparison of revealed market advantage and revealed export advantage as factors of the revealed comparative advantage

Table 4. Regression analysis between harvested production, area and RCA

Analysis of variance (RCA)							
Source	DF	**Sum of squares**	**Mean squares**	**F**	**Pr > F**	**p-values signification codes**	
Model	2.000	10.400	5.200	12.262	0.001	****	
Error	14.000	5.937	0.424				
Corrected Total	16.000	16.337					
Computed against model Y=Mean(Y)							
*Signification codes: 0 < **** < 0.001 < *** < 0.01 < ** < 0.05 < . < 0.1 < * < 1*							

Model parameters (RCA)							
Source	**Value**	**Standard error**	**t**	**Pr > |t|**	**Lower bound (95%)**	**Upper bound (95%)**	**p-values signification codes**
Intercept	3.189	2.134	1.494	0.157	-1.389	7.767	*
Area	-0.454	0.273	-1.661	0.119	-1.040	0.132	*
Harvested production	0.068	0.014	4.911	0.000	0.039	0.098	****
*Signification codes: 0 < **** < 0.001 < *** < 0.01 < ** < 0.05 < . < 0.1 < * < 1*							

Standardized coefficients (RCA)							
Source	**Value**	**Standard error**	**t**	**Pr > |t|**	**Lower bound (95%)**	**Upper bound (95%)**	**p-values signification codes**
Area	-0.274	0.165	-1.661	0.119	-0.627	0.080	*
Harvested production	0.810	0.165	4.911	0.000	0.456	1.163	****
*Signification codes: 0 < **** < 0.001 < *** < 0.01 < ** < 0.05 < . < 0.1 < * < 1*							

Source: Authors' calculations based on Eurostat database (ds-045409)

Regression analysis showed that the model consisting of two explanatory variables – area and harvested production – has a statistically significant explanatory power in relation to the RCA indicator.

In order to verify autocorrelation a Durbin-Watson test has been implemented to the calculation.

Table 5. Durbin-Watson test of harvested production, area and RCA variables

DW	1.639
rho	0.133
p-value (one-tailed)	0.334
alpha	0.05

Source: Authors' calculations based on Eurostat database (ds-045409)

The resulting Durbin-Watson statistical value (Table 5.) of DW = 1.639 indicates a weak positive autocorrelation. The p-value (0.334) exceeds the significance level of 0.05. This result suggests that the regression model satisfies the assumption of independence of residuals, supporting its statistical reliability in terms of autocorrelation. The residuals are not autocorrelated.

Based on the values measured in the regression analysis, it was also possible to identify hypotheses H1 and H2. Hypothesis H1 focused on the positive relationship between RCA and Hungarian plum exports. For the years 2004 to 2020, regression analysis (Table 4.) identified that the coefficient for the variable harvested production had a positive value (0.068) at a significance level of $p < 0.001$. At the same time, based on the results obtained, it was identified that the variable harvested production has a strong influence on RCA (standardized coefficient 0.810). Thus, in the case of the indicator under review, an increase in plum production in Hungary leads to an increase in RCA itself, and the scope of production is a key factor in Hungary's competitiveness in the agricultural commodity of plums on the single EU market.

In the case of hypothesis H2, which examined the positive effect of orchard area on RCA, the measurement results were different. In this case, hypothesis H2 was not confirmed, as the value $\beta = -0.454$ was negative. However, on the other hand, this result was not supported by the required level of significance (measured value p = 0.119). The standardized coefficient was -0.274, which is statistically inconclusive. In view of the above, it was identified in the case of hypothesis H2 that changes in orchard size do not have relevant predictive value or are statistically unreliable when assessing their significance for RCA Hungary in plum production.

Conclusions

Plum production in Hungary has experienced a change in trade dynamics over the observed period (2004-2020). According to the data observed, the area of plum orchards has remained relatively stable (averaging around 7,900 hectares). A more dynamic development was apparent in the yield per hectare, which oscillated between 3.6 and 9.8 tonnes per hectare. This value reflects the yearly variations in climate conditions that fruit growers have experienced in recent decades. Based on these changes, the annual plum production also varied significantly. Production experienced significant changes during the observed period, reaching values ranging from 27,000 to 70,000 tonnes (averaging 47,000 tonnes). Hungary remained an export-oriented country within the EU single market for most of the time, but this changed due to a decrease in production in 2020. The RCA index calculated for the entire period of Hungarian plum production research corresponded with these findings, decreasing to 1.1 in 2020 and indicating that Hungary's once strong comparative advantage in this area had almost been lost by the end of the research period.

Based on previous findings, statistical analysis in the form of regression was conducted to obtain further economic data to support the evidence obtained from initial descriptive statistics and the RCA calculation. These findings provide evidence of the significance of harvested production on the RCA index in relation to the cultivated production area in Hungary. Thus, the results show evidence of a strong association between an increase in output and a subsequent increase in the RCA index value. Thus, we have confirmed the H1 hypothesis. However, changes in the orchard area proved to be a very limited factor affecting the RCA index (rejecting the H2 hypothesis). This shows that achieving higher yields per hectare through improved technology and practices is more important for the sustained competitive advantage of Hungarian plum production in the EU single market than expanding the area of plum orchards. This particular case study provides evidence that land-use efficiency and production intensity have a greater impact on plum competitiveness than land area alone in Hungary during the observed period.

The observed decline in the RCA index, which proves a decline in competitiveness by 2020, is driven by both external factors, such as weather-induced crop shortfalls or growing market competition, and internal factors, such as farm efficiency and infrastructure. This leads to the need for strategic interventions to strengthen Hungary's plum production sector. In order to protect its competitive advantage in the EU single market against other EU countries, targeted measures should be pursued, including investment in technology and innovation, climate variability resilience, value-added processing, and market adaptability.

Conflict of interest

The authors declare no conflict of interest.

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