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Growth instability index, and decomposition effect on production of large cardamom in Nepal

S. M. Dhungana[1*], P. P. Regmi[1], S. C. Dhakal[1] and N. R. Devkota[2]

Abstract

Background Large cardamom is the third most costly and oldest spice in the world, then saffron and vanilla, which is referred to as "black gold." Nepal's exportable, high-value subsector produces large cardamom (*Amomum subulatum* Roxb.) for sale in particular global markets. This study was to assess large cardamom's compound annual growth rate (CAGR), instability index, and influence of decomposition in Nepal. Data were imported from Ministry of Agriculture and Livestock Development, Nepal (MOALD) & Trade Export Promotion Centre, Nepal (TEPC), and the custom office in Birtamod, Nepal, from 2009 to 2020. The compound growth rate was calculated by an exponential function. The area, production, productivity, unit price of large cardamom before export at birtamod custom office, export quantity, and value of large cardamom were evaluated by variation (CV) and the Cuddy–Della Valle index (CDVI). Stability and growth performance were analyzed to assess the proportional impact of area and yield on the overall production of larger cardamom.

Results Area, production, and yield had compound annual growth rate of 1.25, 2.0, and 0.85, respectively, revealing a major expansion of Nepalese large cardamom. The Mechi corridor has proven favorable and rapid development rates, indicating its potential but there was a reduction in large cardamom farming indicating negative CAGR of − 0.68 in the Koshi corridor. The area, production, and yield CV and CDVI were comparatively low, indicated stability in large cardamom farming. With a negative CAGR of − 1.01, the average price showed a downward trend over time. While the export quantity had a positive CAGR of 0.67, the export value had a positive CAGR of 3.84, suggesting a considerable increase.

Conclusions The results emphasized the need for deliberate actions to increase stability, yield levels, market diversification, and lessen reliance on a single market for significant cardamom exports. Finally, prioritizing farmer capacity building programs will increase their proficiency with sustainable farming methods and resource management.

Keywords Compound annual growth rate, Decomposition effect, Instability index, Large cardamom

Introduction

Large cardamom, often known as the "queen of spices," is famous for its delectable perfume and is mostly used as a flavoring component in a variety of culinary preparations. Apart from its culinary worth, this spice has great therapeutic benefit, since it is excellent in treating problems such as sore throats, lung congestion, digestive disorders, and even pulmonary tuberculosis [12]. Large cardamom is also used in the production of beverages,

*Correspondence:
S. M. Dhungana
smdhungana@afu.edu.np
[1] Department of Agricultural Economics and Agribusiness Management, Faculty of Agriculture, Agriculture and Forestry University, Rampur Chitwan, Nepal
[2] Gandaki University, Pokhara, Gandaki Province, Nepal

fragrances, and medications, broadening its usage in a variety of industries. Large cardamom is a rich cash crop that contributes significantly to revenue generation in locations, such as the eastern Himalayas, including Nepal, Bhutan, and certain Indian states [8]. The history of large cardamom may be traced back to Sikkim, India, where Nepalese laborers who migrated there for seasonal employment brought back large cardamom seedlings and suckers, leading to the establishment of large cardamom farming in the region [1].

According to historical documents, Nepalese laborers introduced large cardamom to Nepal, particular the Ilam region, in 1865 [8]. Organized development attempts for large cardamom, on the other hand, began in 1975 with the establishment of the Cardamom Development Centre (CDC) in Fikkal, Ilam district [8]. Following this, specific districts, including Ilam, Panchthar, and Tehrathum, were chosen as cardamom development regions in 1982, with the goal of promoting and expanding extensive cardamom farming throughout Nepal [14]. Currently, large cardamom farming in Nepal involves about 21,960 households spread over 51 districts. Taplejung, Panchthar, Ilam, Sankhuwasaba, and Tehrathum are the key cardamom-producing districts, accounting for more than 80% of total national production [6]. These districts, located in the country's eastern hill and mountain regions, continue to dominate significant cardamom production, with cultivation increasingly spreading to the country's western regions [9].

Large cardamom also referred to as black cardamom is used extensively in Pakistani and Indian savory rice and meat dishes. On the international market, black cardamom from Nepal has a high trading price of into USD 20/kg, while cardamom from other origins, such as Vietnam, commands a significantly lower trading price of around USD 5/kg [3]. Due to the significant price disparity, farmers in the eastern region have shifted their cropping patterns from traditional cereal-based crops and to massive cardamom planting. The switch to large-scale cardamom production has proven financially beneficial, as it provides three to four times the income of traditional crops [11].

The Agriculture Development Strategy (2015–2035) has also prioritized large cardamom as the 12th subsector among 15 designated sub-sectors for agribusiness development in Nepal using a value chain approach [5]. Market diversification of Nepalese agricultural goods with export potential, such as large cardamom, is critical for Nepal. Due to the limited market routes known for speedy delivery, significant large cardamom exports are concentrated in India. As a result, it is critical to determine the most cost-effective modes of transportation and logistics to various portions of other SAARC countries. According to research, cash crop production creates jobs and improves lifestyles [4, 13, 15]. The majority of farmers in sloppy areas tend to gravitate to commercial cardamom growing under the agro-forestry method, where cereals, vegetables, and fruit enterprises are not suited. Among other agricultural crops, cardamom is a prominent commodity with the highest share of export values. Understanding the growth patterns and variables affecting production, pricing, and exports can provide insights into economic potential and market dynamics. Shrestha [9] discovered that the CAGR for the area was increasing at a rate of 0.532. Similarly, production climbed at a CAGR of 0.491. Yield, on the other hand, is dropping by −0.041.

The yield has decreased mostly because of the use of quite old plants in combination with diseases such as chhirke, furkey, and clump rhizome rot [7]. There is still a shortage of virus-free tissue culture saplings and disease-free seedlings available. As a result, farmers are forced to use suckers separated from old mother bushes for planting new plants, which may have aided disease transmission. The absence of technical know-how is another key factor of decreased output, but the government has not provided adequate technical support and training programs [10]; consequently, farmers lack basic orchard management practices. Koshi province is determined to cover more than 90% of the entire area of the country, although it has a negative CAGR of −0.073.

However, the CAGR for the Bagmati, Gandaki, Lumbini, and Karnali was increasing at rates of 4.626, 6.471, 7.331, and 4.913, respectively. Sudhurpaschim province has a negative CAGR of -0.062. For production, Koshi and Sudhurpaschim have negative CAGRs of −0.818 and −0.0147, respectively. Bagmati, Gandaki, Lumbini, and Karnali, on the other hand, have increasing rates with CAGRs of 5.904, 4.676, 5.904, and 4.915, respectively. Though the yield CAGR is improving, it is currently negative in Koshi, Gandaki, Lumbini, Karnali, and Sudhurpaschim, with −0.741, −1.633, −1.673, −1.044, and −0.419, respectively. Bagmati, on the other hand, has a positive yield trend with a CAGR of 1.093. The total area in Koshi province has been expanding, but the CAGR reveals that it has been declining over the last 12 years, affecting production and yield (MOAD, 2016). Other provinces experienced a positive trend. It is attributable to the presence of disease-free large cardamom seedlings planting [9, 10]. In reality, large cardamom is a substantial income crop.

Research methodology

Growths and instability of large cardamom

Using the exponential function, CAGRs were projected to find the percentage change in the parameters. For

this purpose, date was imported from 2009 to 2020 from MOAD, TPC and custom office birtamod, Nepal.

The following exponential function was used to calculate the CAGRs:

$$Y = \text{abte} \tag{1}$$

where Y = area (ha), production (tons) and productivity (Ton/ha), Price Nrs/kg, Export quantity (kg) and export value (Nrs/kg); a = constant; b = Regression coefficient; t = years (1, 2, 3…n); e = Error terms.

Furthermore, the growth function from Eq. (1) was extended as log function:

$$\text{Log Yt} = \text{Log a} + \text{t log b} \tag{2}$$

Finally, the compound growth rate (%) was calculated by the following formula:

$$\text{Compound growth rate}(r) = [(\text{Antilogoflogb}) - 1] * 100 \tag{3}$$

Instability analyses

Instability of selected parameters of large cardamom was assessed using two measures of instability, such as coefficient of variation and Cuddy–Della Valle index. CV can be calculated as follows:

$$\text{CV} = \frac{\text{Standard Deviation}}{\text{Mean}} * 100 \tag{4}$$

The Cuddy–Della Valle index corrects the coefficient of variation in long term trend. It is a best measurement for instability in agricultural. A low value of this index indicates low instability and vice-versa. To correct the CV limitation, the Cuddy–Della Valle index [2] expressed as following:

$$\text{Cuddy} - \text{Della Valle index} = \text{CV}\sqrt{(1 - \text{R}^{'2})} \tag{5}$$

where CV = coefficient of variation; R'^2 = coefficient of determination from trend regression adjusted for its degrees of freedom.

Based on CDVI, instability is grouped as low, medium and high.

below 15 as low instability
15–30 as medium instability
30 and above as high instability

Decomposition analysis

To study the relative contribution of area and yield on the total production of large cardamom in Nepal over a specific time period employed a component analysis model. This model allows for the breakdown of the total change in production into three distinct effects: the yield effect, the area effect, and the interaction effect. The yield effect represents how changes in yield levels influence overall production, the area effect measures the impact of changes in cultivated land area and the interaction effect reflects the combined influence of yield and area changes. Decomposition analysis offers valuable insights into understanding the individual elements contributing to a specific parameter, helping researchers and policymakers gain a comprehensive understanding of large cardamom production dynamics in Nepal:

$$\Delta P = A_0\Delta Y + Y_0\Delta A + \Delta A\Delta Y \tag{6}$$

where (ΔP) = change in production, ΔA = change in area, ΔY = change in yield, A_0 = base year area, Y_0 = base year yield, ΔAΔY = interaction effect.

Results

Trend of large cardamom (area production and yield)

From above table, growth performance of all parameters was quite satisfactory except some region such as Koshi corridor had negative growth rate for area and production; however, interestingly yield parameter had positive growth rate which were not statistically significant. As per data presented in Table 1, Mechi had positive and high growth rate for all parameter which indicated that Mechi corridor has greater potential and contribution of large cardamom production. Nepal experienced CAGR of 1.25, 2.10, and 0.85 for these parameters vis, area, production and yield, respectively, which indicated a significant increase in large cardamom business.

The Mechi corridor showed a higher CAGR of 1.42, while Koshi province experienced growth at a rate of

Table 1 CAGR of large cardamom for selected parameters in study area

Parameter	Study site	CAGR
Area (ha)	Nepal	1.25***
	Koshi province	0.81***
	Mechi corridor	1.42**
	Koshi corridor	−0.68
Production (Mt)	Nepal	2.10***
	Koshi province	1.48***
	Mechi corridor	2.39***
	Koshi corridor	−0.63**
Yield (Mt/ha)	Nepal	0.84**
	Koshi province	0.67**
	Mechi corridor	0.97**
	Koshi corridor	0.06

** and *** indicate 5% and 1% level of significance

Source: MOALD, Nepal

0.81. On the other hand, the Koshi corridor displayed a negative CAGR of −0.68%, indicating a reduction in the large cardamom area. Positive growth rates were also seen in the Mechi corridor and the Koshi province, with CAGRs of 1.48 and 2.39, respectively. The Koshi corridor, on the other hand, saw a negative CAGR of −0.63, which denotes a reduction in large cardamom production. The Koshi province and Mechi corridor both exhibited positive CAGRs of 0.67and 0.97 when yield (Mt/ha) was considered, showing improved yields. The Koshi corridor, on the other hand, had a negligible CAGR of 0.06, indicating relatively steady yield levels (Table 2).

The study area encompassed various geographical domains, including Nepal, Koshi province, Mechi corridor, and Koshi corridor. When the area parameter was examined, it was determined that Nepal had a coefficient of variation (CV) of 10.62, with a coefficient of dynamic variation (CDVI) of 8.20 with statistically significant at 1% level, indicating low instability. Similarly, in Koshi province, the CV was 8.33, and the CDVI was 6.68, also indicating low instability. The Mechi corridor exhibited a CV of 13.25, with a CDVI of 10.16, suggesting low instability. Finally, the Koshi corridor had a CV of 9.68, and a CDVI of 8.88, both pointing to low instability in terms of area production. Shifting focus to the production parameter, the results revealed that Nepal exhibited a CV of 22.19, and a CDVI of 11.41, indicating low instability. Similarly, in Koshi province, the CV was 9.03, and the CDVI was 8.76, both suggesting low instability. The Mechi corridor displayed a CV of 8.55, with a CDVI of 12.72, once again pointing to low instability. Finally, the Koshi corridor had a CV of 13.34, and a CDVI of 5.46, implying low instability in terms of production.

Table 2 Level of instability of selected parameter of large cardamom in study area

Parameter	Domain	CV	CDVI	Inference
Area (ha)	Nepal	10.62	8.20***	Low
	Koshi province	8.33	6.68***	Low
	Mechi corridor	13.25	10.16***	Low
	Koshi corridor	9.68	8.88**	Low
Production (Mt)	Nepal	22.19	11.41***	Low
	Koshi province	9.03	8.76***	Low
	Mechi corridor	8.55	12.72***	Low
	Koshi corridor	13.34	5.46**	Low
Yield (Mt/ha)	Nepal	11.14	7.52**	Low
	Koshi province	13.07	7.52**	Low
	Mechi corridor	12.59	9.02**	Low
	Koshi corridor	18.24	10.46	Low

** and *** indicated 5% and 1% level of significance

Source: MOALD, Nepal

Regarding the yield parameter, the findings indicated that Nepal had a CV of 11.14, and a CDVI of 7.52, both signifying low instability. Similarly, in Koshi province, the CV was 13.07, and the CDVI was 7.52, suggesting low instability. The Mechi corridor exhibited a CV of 12.59, with a CDVI of 9.02, further pointing to low instability. Finally, the Koshi corridor had a CV of 18.24, and a CDVI of 10.46, indicating low instability in terms of yield. To summarize, based on the instability index, the study's results indicated that the area, production, and yield of large cardamom in the study area experienced low instability across different geographical domains.

The impacts of area, yield, and their interactions on the production of large cardamom were presented in Table 3 for Koshi corridor, Mechi corridor, Koshi province, and Nepal. When the area effect was examined, it was found that the Koshi corridor had a negative area effect on productions of −64.23. Similar results were found in the Mechi corridor, where production was negatively impacted by an area effect of −138.02. At −223.69, the area effect was much more significant in the Koshi province. Last but not least, the area effect for the entire nation of Nepal was −46.81, indicating a detrimental effect on production. Regarding the yield effect, it was discovered that in the Koshi corridor, the yield had a favorable impact on production of 151.18. An even greater yield effect of 210.55 was seen in the Mechi corridor, indicating a more significant contribution to production. The Koshi province has the largest yield effect of any location, at 287.02. The yield effect for Nepal as a whole was 134.35, indicating a favorable impact on production. The results indicated a negative impact in the interaction effect, which considered the combined influence of area and yield. The interaction effect in the Koshi corridor was −13.06, shown that the interaction between area and yield had a negative impact on production. Similar trends were seen in the Mechi corridor and Koshi province, with interaction effects of −27.47 and −36.67, respectively. The interaction effect for Nepal as a whole was −12.45.

Prior to time, the emergence of diseases and pests can be responsible for the detrimental effects of the area under cultivation and the interaction between area and

Table 3 Decomposing effect on production with area, yield and their interaction of large cardamom in Nepal

Effect	Koshi corridor	Mechi corridor	Koshi province	Nepal
Area effect	−64.23	−138.02	−223.69	−46.81
Yield effect	151.18	210.55	287.02	134.35
Interaction effect	−13.06	−27.47	−36.67	−12.45

Source: MOALD, Nepal

Table 4 Compound annual growth rate (CAGR) of price, export quantity and export value of large cardamom in Nepal

Indicators	CAGR
Price (Nrs/kg)	−1.01
Export value (000 NRs)	3.84***
Export quantity (kg)	0.67

Source: TPC, Birtamod custom office

Table 5 Instability index of price, export quantity and export value of large cardamom in Nepal

Indicators	CV	CDVI	Inference
Price (Nrs/kg)	21.25	20.44	Medium
Export value (000 NRs)	34.64	23.25***	Medium
Export quantity (kg)	28.69	29.26	Medium

Source: TPC, Nepal

yield on production. Later on, even though the growing area with disease-free sapling and high-yielding variety quickly expanded, these plants have not yet achieved their anticipated productive phase.

In Table 4, it is shown that the compound annual growth rate (CAGR) for three variables connected to large cardamom in Nepal—price, export value, and export quantity—was determined. Price (Nrs/kg) has a CAGR of −1.01, which is a declining growth rate. This implies a decrease in the large cardamom average price per kilogram for the given time frame. However, the export value displayed a positive CAGR of 3.84, which is highly significant statistically. It suggests that the money made from the export of huge cardamom has significantly grown. The CAGR for export quantity was 0.67, which is a positive growth rate.

Three indicators of large cardamom in Nepal are given in Table 5, along with the stability index for each. The CV for price was 21.25, indicating a moderate degree of price instability for large cardamom. This suggested that prices varied over the course of the time period. The CDVI of 20.44 further reinforced the conclusion of medium-term price instability. Similar, the CV for large cardamom export values was 34.64, indicating a comparatively higher level of instability. This demonstrated that the export values varied significantly during the time span. The CDVI, however, was 23.25, indicating a statistically significant medium level of export value instability. The export quantity also showed a CV of 28.69, showing a high degree of instability in the quantity of large cardamom exported. This indicated that there had been substantial fluctuations in export volume over the period. The medium level of export quantity instability was further exacerbated by the CDVI of 29.26.

Discussion

Looking the parameter area, production and yield, Nepal experienced CAGR of 1.25, 2.10, and 0.85, respectively, which indicated a significant increase in large cardamom business with same line to a study conducted by Shrestha [9] the CAGR for Nepal, area production and yield shown that area was increasing with 0.532 and 0.491 on the contrast yield is decreased by −0.041. The other major cause of declining yield of lack of technical knowhow of farmers for which the government has not provided sufficient technical support and training program [10]. The yield is decreasing mainly due to very old plantation/orchard accompanied with devasting disease, such as *chirke, furkey* and clump rhizome rot [7], there were limited availability of virus-free tissue culture sapling as well disease-free seedling. Therefore, farmers are forced to use sucker separated from old mother bushes for planting new plantation/orchard which might have favored transmission of disease. However, recently, it has increased due to disease-free tissue culture and new plantation. The Agriculture Development Strategy (2015–2035) has also prioritised large cardamom as the 12th sub-sector among 15 designated sub-sectors for agribusiness development in Nepal using a value chain approach [5]. Then, establishment of tissue culture centre and registration of new variety.

It is well-known that variability in area and production is interrelated if other factor remains constant than the growth in area gives the highest production but variation in productivity may be due to many reasons, such as weather conditions, policy changes etc. Some other factors such as price also bring the variation in production of large cardamom. Nepalese farmer grown the large cardamom for sale rather than household consumption. While concerning with instability of different aspect of large cardamom such as area production, yield price and export had low instability. Most locations with extensive cardamom cultivation and marketing have exceptionally low instability indices, indicating minimal risks. This is a fantastic chance for Nepal to focus on market diversification and investigate the export possibilities of this precious commodity. Due to limited known market routes for timely delivery, the export destination for large cardamom has centered on India. However, this reliance on the Indian economy may offer future dangers of instability. As a result, it is critical for Nepal to broaden its export horizons and seek new markets to ensure a sustainable and secure future for the vast cardamom trade.

Conclusion

With noteworthy exceptions in the Koshi corridor, where both area and production witnessed negative growth, the growth performance has generally been good. Interestingly, despite not being statistically significant, the yield increased. Mechi corridor, which boasts better growth rates across all parameters, emerges as a potential hotspot for extensive cardamom production. The large cardamom has expanded significantly in Nepal as a whole, as seen by the country's notable Compound Annual Growth Rates (CAGRs). Stability analysis shows low instability across several geographic domains, highlighting the ideal setting for investment and development in the sizable cardamom sector. The continuation of this stability is essential for sustainable trade and production. The effects of area, yield, and their interactions on production differ by location, with negative area effects in the Koshi and Mechi corridors calling for focused interventions and positive yield effects highlighting the value of increasing yield through modern agricultural practices. Tailored measures should specifically target the problems in the Koshi corridor and offer farmers technical and financial support. Promoting geographic heterogeneity can help to more fairly distribute the advantages. Furthermore, giving priority to capacity building programme for farmers will improve their expertise in resource management and sustainable farming techniques.

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Author contributions
Surya Mani Dhungana has prepared the research design and implementation a research plan. Moreover, he analyzed the data and prepared the manuscript. Prof. Dr. Punya Prasad Regmi, Prof. Dr. Nabaraj Devkota, Associate Prof. Dr. Shiva Chandra Dhakal advised and provided comments and feedback to finalize this manuscript. All authors approved the manuscript.

Data availability
Data will be provided on request.

Declarations

Ethics approval and consent to participate
No human and animal were used as research unit.

Consent for publication
NA.

Competing interests
The authors declare no conflict of interest.

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