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The sustainability status of cut rose farming in Batu City: Uncovering data and facts from Indonesia's largest cut rose producing city

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ABSTRACT

Batu City, East Java, produces the most cut roses in Indonesia. The city's cut rose cultivation has long been the primary source of income for local farmers. However, cut rose producers face many issues that imperil their farms. Therefore, this study aimed to analyze the sustainability status of cut rose flower farming and sensitive indicators that affect its sustainability. This research was conducted in October 2024. Structured interviews with 155 rose-cut farmer respondents provided this study's primary data. The data analysis method used was multidimensional scaling (MDS). The results of the study show that the sustainability of cut rose farming in Batu City is categorized as "quite sustainable" with an average score of 62.57. This empirical fact suggests that the farm has a sufficiently long period to continue cultivation. Then, the sensitive indicators significantly affecting ecological sustainability were the land elevation, chemical fertilizer use, and crop waste management. Regarding economic sustainability, the most sensitive indicators were the farm profit, market scale, and market chain. Next, the most sensitive indicators affecting social sustainability were the intensity of extension, farming experience, and family participation in farming. Finally, the sensitive indicators that most influence the sustainability of technological innovation are transportation technology, the adoption of environmentally friendly cultivation innovations, and marketing technology. The results suggest that cut rose farming could be more sustainably run if specific key indicators were addressed; these include steep land slopes, a lack of marketing and promotion, frequent disputes among farmers, and inadequate cultivation technology.

1. Introduction

The rapid growth of urbanization in urban areas is raising many concerns about the future of urban agriculture (Salim et al., 2022). Currently, urban agriculture challenges include limited area, fierce market rivalry, and legislative constraints (Opitz et al., 2016).

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Agricultural operations in urban environments are called "*good stewards*" (Toku et al., 2024) that have many benefits in line with the UN sustainability goals across multiple dimensions (Nesheli and Salaj, 2024). Urban agriculture has the potential to mitigate poverty, empower communities, and promote entrepreneurship in urban areas, thereby addressing economic disparities. Entrepreneurs and local businesses are critical actors in the urban sustainability transition, as the increasing prevalence of agriculture in urban areas contributes to the reduction of poverty and the creation of employment opportunities (Muñoz and Cohen, 2016). Horticulture is one of the most common urban business commodities. Horticultural commodities are Indonesia's strongest national income supporter (Sundari et al., 2021). Horticulture has four types of groups: fruits, vegetables, ornamental plants, and biopharmaceutical plants (Mahmudi et al., 2024). One type of horticulture in great demand by urban consumers is ornamental plants.

Ornamental plants are urban agribusiness commodities with significant growth potential in Indonesia (Tiasmalomo et al., 2020). One type of ornamental plant developed for both domestic and export markets is the rose (Puspasari et al., 2017). Roses (*Rosa hybrida* L.) are a globally significant ornamental plant, possessing significant symbolic, cultural, and economic value (Meral et al., 2025), (Cheng et al., 2021), (Raymond et al., 2018), (Smulders et al., 2019). Roses are the most frequently produced cut flower and are acknowledged as the premier cut flower in the global floriculture industry (Leus et al., 2018). Roses lead the list of the top ten cut flowers in the international market (Philip et al., 2019). In Indonesia, the demand for cut roses tends to increase significantly in some provincial capitals such as DKI Jakarta, East Java Province, and Bali Province (Nugroho et al., 2022). In East Java Province, Batu City is the highest producer and supplier of cut roses in Indonesia (Pratama, 2021). Since 2005, Batu City has been the highest cut rose production center in Indonesia. Cut rose farming in Batu City has long developed and become the main livelihood for local farmers. The average income of cut rose farmers in Batu City is IDR 202,273,845 to IDR 522,643,541 per hectare per planting season (Puspitasari, 2018). This farming business certainly contributes greatly to the regional economy, especially in the agriculture and tourism sectors. Over the last four years, rose production in the city has increased, whereas it previously experienced a significant decline, as shown in Fig. 1.

Fig. 1 shows that the harvest area, production, and productivity of cut roses in Batu City fluctuated from 2014 to 2023. Surprisingly, all three data points experienced a significant decline in 2020 during the Covid-19 pandemic. In 2020, the rate of decline in harvested area was −6 %, the rate of decline in production was −52 %, and the rate of decline in productivity was −49 %. Prior to the COVID-19 pandemic in 2019, farmers had already been facing various challenges (Wahyudi et al., 2022) such as the high attack of pests and plant diseases, rose cultivation located on steep slopes, lack of marketing (promotion), fluctuating market prices, many conflicts between farmers, low educational levels among farmers, insufficient use of cultivation technology, insufficient use of information and communication technology, and many more (Kartikasari, 2017), (Puspitasari, 2018), (Supiyatun, 2018), resulting in production fluctuations from 2014 to 2018. Then, entering the Covid-19 pandemic era, farmers' problems became even more complex because farmers were not only faced with problems related to their farming activities, but also problems related to non-farming aspects such as health, social, economic, and others. Therefore, production in 2020 experienced a very sharp decline.

Even after the COVID-19 pandemic, farmers are still grappling with the aforementioned issues, resulting in suboptimal production of cut roses year after year. These issues serve as indicators representing various dimensions, including ecology, economy, society, technology, and innovation. These four dimensions will undoubtedly influence the sustainability of cut rose farming in Batu City. This is because the concept of sustainability itself is supported by three key pillars: economy, environment, and society (Klarin, 2018), (Lim et al., 2018), (Mota et al., 2015), (Prandelli et al., 2024), (Purvis et al., 2019), (Wolfert and Isakhanyan, 2022). Meanwhile, the previous study by Tiasmalomo et al. (2021) added the technology pillar as a crucial research parameter for assessing the sustainability status of ornamental plant farming, as technology is closely related to more optimal and efficient resource use and increased agricultural productivity. Therefore, the SDGs should be understood more comprehensively, examining the relationships and interactions between indicators within each dimension and across dimensions (Castañeda et al., 2018), (Nilsson, 2017), (Pradhan et al., 2017). Sustainability analysis can be performed using the MDS (*Multidimensional Scaling*) technique. MDS is a multivariate statistical analysis that transforms each dimension and multidimensional sustainability (Tiasmalomo et al., 2021). Therefore, this study sought to analyze the sustainability status of cut rose farming and sensitive indicators that affect its sustainability in Batu City, Indonesia. The study's findings are expected to contribute to the development of cut rose commodities and encourage innovative and sustainable agricultural practices. The development of cut rose farming in Batu City is highly likely to align with the SDGs' pillars. Cutting rose farming in this city is financially profitable and has a positive impact on the environment and society.

2. Literature review

2.1. Ecological dimension

The ecological dimension emphasizes the stability of natural ecosystems, which encompass biological life systems and natural materials (Wigiani et al., 2019). The ecological dimension in the context of sustainability refers to efforts to preserve and restore ecosystems, protect biodiversity, and ensure the sustainability of ecosystems throughout all regions, including urban areas, as in the research conducted by Delgado-Ramos and Guibrunet (2017). Meanwhile, the research by Zulkarnaini (Zulkarnaini et al., 2022) also focuses on the ecological dimension

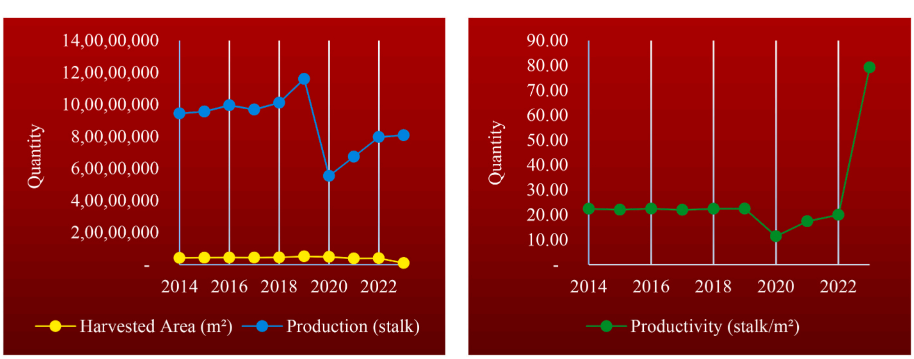

Fig. 1. Harvest area, production, productivity of cut roses in Batu City from 2014 to 2023.
Source: (Dinas Pertanian dan Ketahanan Pangan Kota Batu, 2024).

as the main concept in the context of sustainability. This dimension emphasizes the importance of harmony between humans and nature, where the exploitation of natural resources must be carried out wisely and responsibly so as not to damage the environment and threaten the survival of future generations. Environmentalists are increasingly taking an active role in economic decision-making as they become familiar with environmental practices that aim to enhance socio-economic development. Environmentalists are increasingly involved in every development project to provide solutions for improving air and water quality, conserving natural resources, and promoting economic growth to achieve effective environmental management (Muscalu et al., 2016). Ecological sustainability requires maintaining stable resources, avoiding natural resource exploitation, and preserving ecosystem services.

2.2. Economic dimension

The economic dimension seeks to create a balanced and sustainable economy through the continuous production of commodities and services (Duran et al., 2015). The economic dimension encompasses the diverse components of the economic system that influence the production, distribution, and consumption of resources in society. It includes macro and microeconomics, production, distribution, consumption, and market interactions. Overall, the economic dimension helps to understand how societies manage limited resources to meet unlimited needs. Economic sustainability is assessed in terms of effectiveness, efficiency, and operational productivity over the long term (Alsayegh et al., 2020). Economic sustainability necessitates the establishment of a delicate equilibrium between environmental conservation and economic expansion. This means reaping the benefits of economic development while conserving environmental quality (Tenaw and Beyene, 2021).

2.3. Social dimension

Several studies show that the social dimension has received less attention or has been completely sidelined (Bullard et al., 2012). Social sustainability is the least developed among the three dimensions of sustainable development. There has been considerable research on the economic and environmental dimensions, but much less on the social dimension (Sutherland et al., 2016). The social dimension is the dimension that represents the most variation in indicator selection (Strezov et al., 2017). The social component encompasses a diverse array of concerns, such as safety, equality, diversity, governance, human health, labor rights, and justice. Thus, the social dimension is a significant factor when determining the possibilities, challenges, and benefits of an evaluation (Sutherland et al., 2016). Social sustainability reflects the interaction relationship between development and the prevailing social norms in society.

2.4. Technology and innovation dimensions

Law No. November 2019 on the National System of Science and Technology defined technology as a technique, method, or process of applying and exploiting diverse scientific disciplines that are effective in addressing human requirements, ensuring continuity, and increasing the quality of life. Then innovation is the product of thinking, study, development, assessment, application that contains elements of originality, has been applied, produces economic, and social benefits (Undang-undang (UU), 2019). Developing countries' key innovation challenge is building their capacity to learn, adopt, and disseminate knowledge to promote sustainable and inclusive development. Technology and innovation have been widely recognized as a trigger and catalyst towards sustainability (Dwivedi et al., 2023), (Dzhunushalieva and Teuber, 2024), (Kasinathan et al., 2022), (Kristoffersen et al., 2020). Research by Deguchi (Delgado-Ramos and Guibrunet, 2017) emphasizes the need to convert a society into one that is more inventive by utilizing sophisticated technologies to offer value to businesses. Innovation and technology are critical to facilitating long-term business decisions. Several researchers have highlighted the significance of technology and innovation in attaining sustainability (Omri, 2020).

2.5. Research gaps and conceptual frameworks

2.5.1. Research gaps

Research gaps serve as the foundation for further investigation (Müller-Bloch and Kranz, 2015). Research gaps can be seen differently; what one researcher considers a gap may not be perceived as such by another. As a result, the perception of research gaps varies depending on the eye of the beholder (Miles, 2017). In general, research gaps are identified as inadequacies in the information pool (Müller-Bloch and Kranz, 2015). The seven types of research gaps identified by Miles (2017) are: (a) evidence gaps; (b) knowledge gaps; (c) practical knowledge gaps; (d) methodological gaps; (e) empirical gaps; (f) theoretical gaps; and (g) population gaps. (Jacquet and van der Does, 2021); (Bullard et al., 2012) add one more type of gap, which is a conceptual gap. Therefore, it is necessary to identify research gaps in this article to demonstrate that previous research has limitations or shortcomings, thereby justifying the need for this research and its substantial contribution. The authors found several gaps in previous studies (Table 1). The methodological gap we saw was in data analysis. Previous studies have relied solely on data analysis and commonly used software, leading to no innovative research developments that yield truly new findings. Therefore, a different data analysis method, namely Multidimensional Scaling (MDS) analysis, was adopted with the help of the R software. This data analysis created new insights and perspectives and accurately solved complex research questions. This analysis is also capable of exploring various dimensions effectively and efficiently. The knowledge gap found relates to the research topic. Then, the subject of "sustainability" was raised, which is an important phenomenon or issue today, as it represents a gap in previous research. Furthermore, we found conceptual gaps related to the aspects/dimensions studied. Hence, it is believed that the last research needs to be comprehensive so that exploration is not limited. Meanwhile, our research encourages extrapolating various dimensions (multidimensional), namely 1). ecology, 2). economy, 3). social, 4). technology and innovation. From the explanation above, it can be concluded that this research is exciting and different from previous studies because this cut rose research raises the topic of "sustainability" with the Multidimensional Scaling (MDS) approach. In addition, this research tries to examine a broader problem with different aspects/dimensions. Thus, this research can complement and improve previous research.

2.5.2. Conceptual framework

From a statistical standpoint, a conceptual framework illustrates the relationship between the main topics of a study. It is structured logically to provide an overview or visual representation of how the issues in a study relate to each other (Grant and Osanloo, 2014). This framework will assist researchers identifying and defining the concepts in the study problem. A conceptual framework offers many benefits to a study, such as helping researchers identify and build a view of the phenomenon to be investigated. Research on cut rose farming has been widely conducted as described in the previous chapter, but these studies are only related to social and economic aspects. At the same time, this research offers something much different and more enjoyable. This research on the sustainability of cut rose farming is built on four dimensions (aspects), namely 1) ecological; 2) economic; 3) social; and 4) technology and innovation. Each dimension has seven indicators with a total of 28 research indicators, namely: 1) slope; 2) land elevation; 3) chemical pesticide use; 4) chemical fertilizer use; 5) pest and plant disease attack; 6) plant waste management; 7) plant waste utilization; 8) capital source; 9) market scale; 10) market destination; 11) market chain; 12) farm profit; 13) market price; 14) marketing (promotion); 15) education level; 16) extension intensity; 17) farming experience; 18) family

Table 1
Research gaps.

No.	Previous research				Current research			Conclusions		
	References	RM*	RT	RC	RM*	RT	RC	Differences in	Shortcomings and limitations of previous research	Types of research gaps
1	Hasan et al. (2019)	MLR	Profitability	Social and economic	MDS	Sustainability	Ecology, economy, social, technology and innovation	Data analysis, topic, dimensions explored	Methodology, knowledge, concept	Methodological gap, knowledge gap, conceptual gap
2	Sofiana et al. (2022)	MLR	Marketing profit	Economic						
3	Haque et al. (2013)	CDF	Efficiency	Economic						
4	Putri et al. (2023)	SFA	Efficiency	Economic						
5	Puspasari and Ningrum (2023)	CA	Consumer preferences	Social and economic						
6	Abbas et al. (2024)	NA	Production costs	Social and economic						
7	Gaddi et al. (2024)	CRA; CBT	Comparative analysis	Economic						
8	Pawar and Waghmare (2019)	DA; EA	Supply chain	Economic						

Notes: RM = Research methodology (Data analysis); RT = Research topic; RC = Research concepts (Aspects/Dimensions explored).
*MLR = Multiple Linear Regression; CDF = Cobb-Douglas Function; SFA = Stochastic Frontier Analysis; CA = Conjoint Analysis; NA = Narrative Analysis; CRA = Cost and Return Analysis; CBT = Capital Budgeting Techniques; DA = Descriptive Analysis; EA = Economic Analysis; MDS = Multidimensional Scaling.

participation in farming; 19) local labor absorption; 20) land ownership status; 21) conflict between farmers; 22) adoption of environmentally friendly cultivation innovations; 23) adoption of digital marketing innovations; 24) cultivation technology; 25) information and communication technology; 26) transportation technology; 27) shipping technology; 28) marketing technology (promotion) can be seen in Fig. 2.

3. Research methods

3.1. Research flow chart

The flowchart in Fig. 3 outlines the research steps carried out systematically. This flowchart displays the flow of research in a clear and structured manner, from determining the location and time of research, data collection, and data analysis, to analysis results (output). With this flow chart, the researcher can follow this guide effectively to achieve the expected research objectives. The flowchart also helps to ensure that each stage of the research is carried out correctly and no steps are missed, resulting in valid and reliable findings.

3.2. Research time and location

This research was conducted in October 2024. The research was in Batu City, East Java Province, Indonesia (Fig. 4). Batu City was deliberately chosen as the research location due to its status as the largest rose production center in Indonesia. Batu City is one of the cities in East Java Province, which is geographically located between 7°44'.55.11 ″ −8°26'.35.45 ″ South latitude and 122°17'.10.90 ″ - 122°57'.00.00 ″ East longitude. The area of Batu City is 199.09 km^2 or 19,909 ha.

In general, the Batu City area is hilly and mountainous. Among the mountains in this city, three mountains have been recognized nationally, namely Mount Panderman, Mount Welirang, and Mount Arjuno (Kurniawan et al., 2017). Meanwhile, the land slope is 25–40 %. Judging from the geological formations above, it shows that this city is a fertile area for agriculture because the type of soil is sediment from a series of mountains that surround it, so that the agricultural sector dominates the livelihood of the population (Triatmanto, 2021).

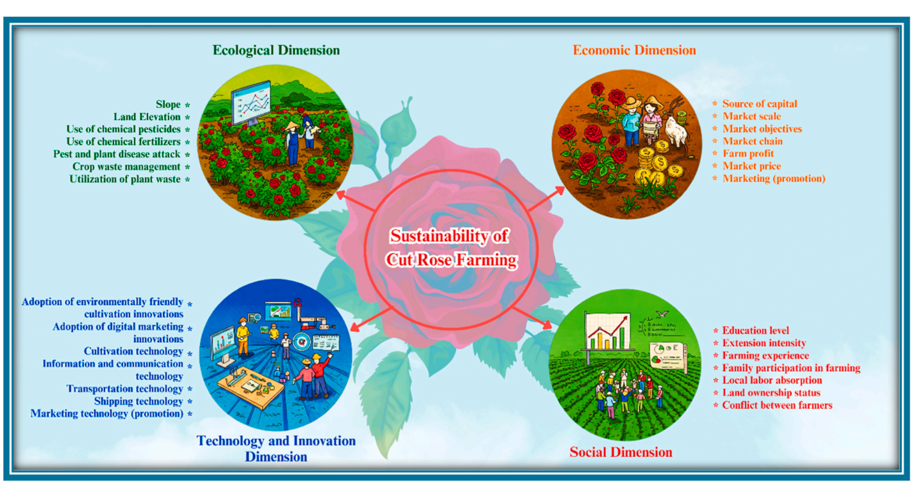

Fig. 2. Conceptual framework for the sustainability of cut rose farming.

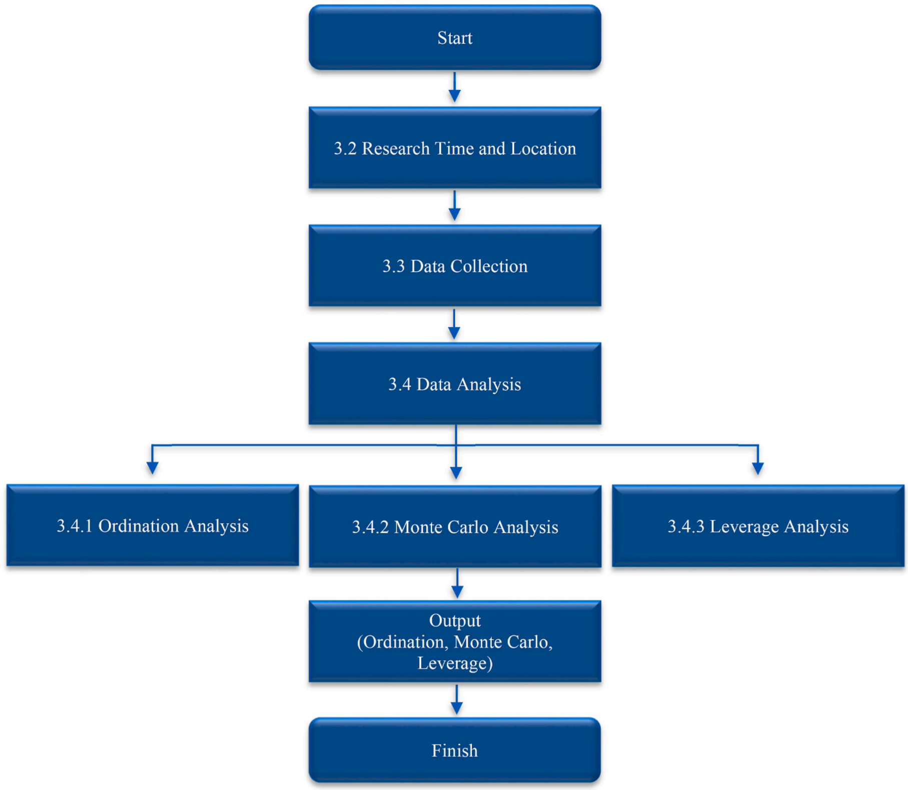

Fig. 3. Research flow chart.

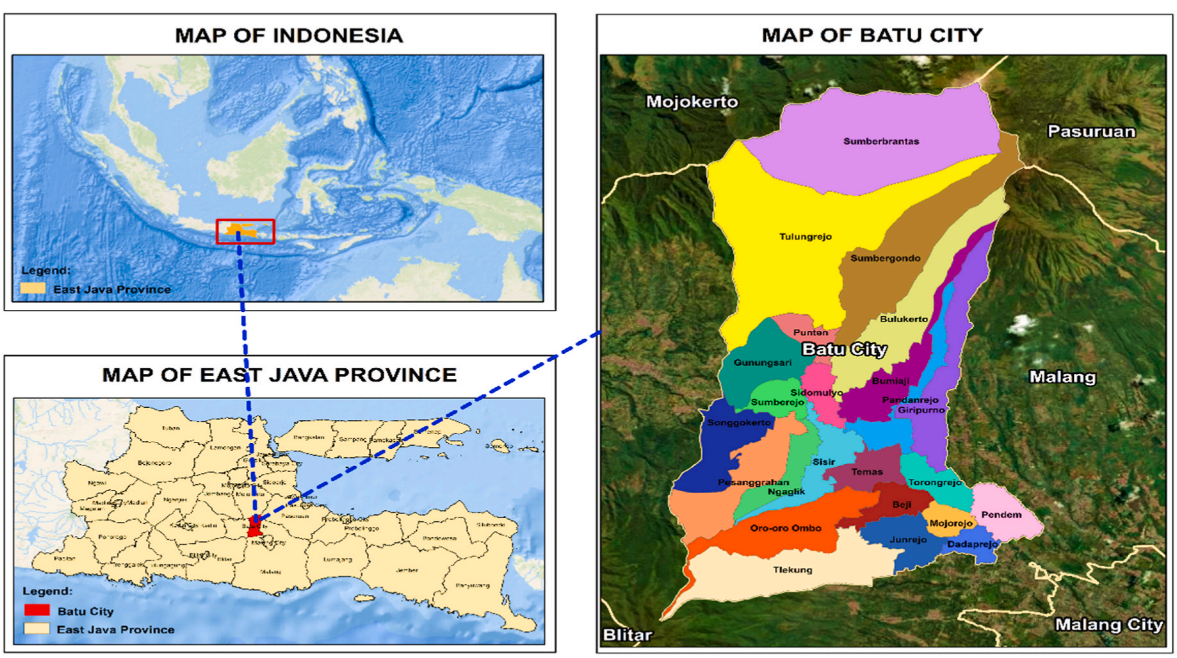

Fig. 4. Research location.

3.3. Data collection

The type of data used in this study is quantitative primary data. Primary data was obtained from structured interviews with cut rose farmers using a prepared questionnaire. The survey method was used in this research. This method collects all information using a questionnaire as a research instrument (Maidiana, 2021). Respondents were chosen using a random sampling method, which assures that every member of the population has an equal chance of being chosen as a respondent (Noor et al., 2022), (Senaweera et al., 2021), (Siegel and Wagner, 2022). Thus, ensuring that the population is unbiased, representative, and has the same probability. The total population of rose farmers in Batu City is 279 farmers spread across 14 villages, namely Sumberejo Village, Sisir Village, Sidomulyo Village, Temas Village, Giripurno Village, Pandanrejo Village, Bumiaji Village, Bulukerto Village, Punten Village, Tulungrejo Village, Sumbergondo Village, Gunungsari Village, Junrejo Village, and Dadaprejo Village (Dinas Pertanian dan Ketahanan Pangan Kota Batu, 2024). Then, the determination of the number of respondents in this study was calculated based on the Isaac and Michael Formula (Sugiyono et al., 2018) as shown in Equation (1), so that 155 sample respondents were obtained.

$$S = \frac{\lambda^2.N.P.Q}{d^2(N-1) + \lambda^2.P.Q} \quad (1)$$

$$S = \frac{3,841\ x\ 279\ x\ 0,5\ x\ 0,5}{0,05^2(279-1) + 3,841\ x\ 0,5\ x\ 0,5} = 155$$

Notes: S = number of samples; λ^2 = Chi Square value (3.841) based on degrees of freedom (dk = 1) and 5 % error rate; N = number of population; P = probability of being correct (0.5); Q = probability of being incorrect (0.5); d^2 = degree of accuracy expressed as a proportion (0.05).

3.4. Data analysis

The sustainability of cut rose farming is measured using MDS techniques through RAP-ROSE (Rapid Appraisal for Rose) analysis. RAP-ROSE is a modification of RAP-FISH (Rapid Appraisal for Fisheries) developed by the University of British Columbia (Fauzi, 2019) to measure the sustainability of the marine fisheries sector (Saragih et al., 2020). MDS is a multivariate method that is capable of processing metric data on either a nominal or ordinal scale. This method is a statistical analysis technique that is suitable for use in this study because it accurately and rapidly describes the sustainability status of cut rose farming in Batu City. This method's benefit is that it may generate a large amount of quantitative information by summarizing diverse data collected in the field (Firmansyah, 2016). The sustainability of cut rose farming is evaluated from a broader perspective using four essential dimensions: 1) ecological; 2) economic; 3) social; and 4) technology and innovation. Each dimension consists of several measurement indicators. In this study, R *software* was used to analyze the sustainability of cut rose farming. Before entering the three stages of analysis (Ordination, Leverage, and Monte Carlo), the prerequisites and rules that must be met to operationalize the analysis are:

1) Determine indicators for each dimension of sustainability. The number of good indicators in each dimension is > 6 indicators to produce a good ordination (Pitcher and Preikshot, 2001). So, there are seven indicators for each dimension in this study.
2) Determine the unit of analysis for each village in Batu City. The number of units analyzed is equal to the number of indicators. However, the best is 2–3 times the number (Pitcher and Preikshot, 2001) to avoid outliers that will affect ordination. Therefore, the number of analysis units in this study was 14 units.
3) Determine the score on each indicator with a value range of 0–10. The scoring rules have changed from the 2000 version, which was initially zero (0) to four (4) to zero (0) to ten (10) in the 2013 version and above (Pitcher et al., 2013).

The three things above are summarized in Table 2 to show transparency and clarify the measurement of the parameters of this study. Subsequently, the sustainability analysis of cut rose farming is described in the following stages:

3.4.1. Ordination analysis

The ordination analysis aims to map the points of analysis units based on their level of sustainability on a scale of "bad" and "good". The properties of "distance" between the analyzed cases will be maintained while this ordination analysis transforms multidimensional statistics

Table 2
Dimensions, indicators, units of measurement, sources.

No.	Dimensions	Indicators	Unit of Measurements (Ordinal)*	Source
1	Ecology	Slope	[score 0–2 = >45 %]; [score 3–4 = 25–45 %]; [score 5–6 = 15–25 %]; [score 7–8 = 8–15]; [score 9–10 = 0–8 %]	Madani et al. (2022)
2		Land elevation	[score 0–5 = 350–700 m above sea level]; [score 6–10 = >700 m above sea level].	('Peraturan Menteri Pertanian Nomor 47)
3		Use of chemical pesticides	[score 0–1 = 1 principle of chemical pesticide use]; [score 2–3 = 2 principles of chemical pesticide use]; [score 4–5 = 3 principles of chemical pesticide use]; [score 6–7 = 4 principles of chemical pesticide use]; [score 8–9 = 5 principles of chemical pesticide use]; [score 10 = 6 principles of chemical pesticide use].	Dani et al. (2024)
4		Use of chemical fertilizers	[score 0–2 = 1 principle of chemical fertilizer use]; [score 3–5 = 2 principles of chemical fertilizer use]; [score 6–8 = 3 principles of chemical fertilizer use]; [score 9–10 = 4 principles of chemical fertilizer use].	Hartono et al. (2022)
5		Pest and plant disease attacks	[score 0–2 = >85 %]; [score 3–5 = 50–85 %]; [score 6–8 = 25–50 %]; [score 9–10 = <25 %]	Direktorat Perlindungan Tanaman Pangan (2018)
6		Plant waste management	[score 0–2 = Not at all]; [score 3–5 = 1–2 times a month]; [score 6–8 = 3 times a month]; [score 9–10 = ≥ 4 times a month]	Tiasmalomo et al. (2021)
7		Utilization of plant waste	[score 0–2 = Not at all]; [score 3–5 = Sold]; [score 6–8 = Self-utilized]; [score 9–10 = Sold and self-utilized]	Tiasmalomo et al. (2021)
8	Economy	Source of capital	[score 0–2 = Loan shark capital]; [score 3–4 = Bank loan capital]; [score 5–6 = Family loan capital]; [score	Talha (2017)

(continued on next page)

Table 2 (*continued*)

No.	Dimensions	Indicators	Unit of Measurements (Ordinal)*	Source
			7–8 = Grant or subsidy capital]; [score 9–10 = Own capital]	
9		Market scale	[score 0–2 = None]; [score 3–4 = <2 markets]; [score 5–6 = 3 markets]; [score 7–8 = 4 markets]; [score 9–10 = >4 markets]	Tiasmalomo et al. (2021)
10		Market objectives	[score 0–2 = Local]; [score 3–5 = National]; [score 6–8 = International]; [score 9–10 = National and International]	Talha (2017)
11		Market Chain	[score 0–2 = Farmer - Middleman - Partner Company - Consumer]; [score 3–5 = Farmer - Partner Company - Consumer]; [score 6–8 = Farmer - Middleman - Consumer]; [score 10-9 = Farmer - Consumer]	Puspasari et al. (2017)
12		Farm profit	[score 0–3 = Loss]; [score 4–7 = Break-even]; [score 8–10 = Profit]	Tiasmalomo (2020)
13		market price	[score 0–2 = Decreasing]; [score 3–5 = Fluctuating]; [score 6–8 = Constant]; [score 9–10 = Increasing]	Talha (2017)
14		Marketing (promotion)	[score 0–2 = Not at all]; [score 3–5 = 1–2 times a month]; [score 6–8 = 3–4 times a month]; [score 9–10 = ≥ 4 times a month]	Puspasari et al. (2017)
15	Social	Education level	[score 0 = Not in School]; [score 1 = Not completed primary school]; [score 2 = completed primary school]; [score 3 = not completed junior high school]; [score 4 = completed junior high school]; [score 5 = High School Not Completed]; [score 6 = High School Diploma]; [score 7 = Diploma/ Bachelor's Degree Not Completed]; [score 8 = Diploma/ Bachelor's Degree Completed]; [score 9 = Masters/Doctorate Not Completed]; [score 10 = Masters/Doctorate Completed].	Falo et al. (2021)
16		Extension intensity	[score 0–2 = Not at all]; [score 3–4 = < 4 times a year]; [score 5–6 = 4–5 times a year]; [score 7–8 = 6–7 times a year]; [score 9–10 = ≥ 7 times a year]	Ekopsi et al. (2023)
17		Farming experience	[score 0–2 = ≤2 years]; [score 3–4 = 3–5 years]; [score 5–6 = 6–8 years]; [score 7–8 = 8–10 years]; [score 9–10 = ≥ 10 years]	Ekopsi et al. (2023)
18		Family participation in farming	[score 0–2 = None at all]; [score 3–5 = 1–3 people]; [score 6–8 = 4–5 people]; [9–10 = ≥5 people]	Samudra (2022)
19		Local labor absorption	[score 0–2 = None at all]; [score 3–5 = 1–3 people]; [score 6–8 = 4–5 people]; [9–10 = ≥5 people]	Tiasmalomo (2020)
20		Land ownership status	[score 0–3 = Rent]; [score 4–7 = Share/share]; [score 8–10 = Owned]	Zuhdi et al. (2021)
21		conflict between farmers	[score 0–3 = Never]; [score 4–7 = 1–3 conflicts]; [score 8–10 = >3 conflicts]	Puspasari et al. (2017)
22	Technology and innovation	Adoption of environmentally friendly cultivation innovations	[score 0–3 = Not yet]; [score 4–7 = Only partially]; [score 8–10 = Completely]	Mucharam (2022)
23		Adoption of digital marketing innovations	[score 0–3 = Not yet]; [score 4–7 = Still starting adoption]; [score 8–10 = Already implemented]	Kartikasari (2017)
24		Cultivation technology	[score 0–2 = None]; [score 3–5 = 1–2 tools]; [score 6–8 = 3–5 tools]; [score 9–10 = ≥ 6 tools]	Nuraina (2021)
25		Information and communication technology	[score 0–2 = None]; [score 3–5 = 1–2 tools];	Situmorang (2023)

(*continued on next page*)

Table 2 (*continued*)

No.	Dimensions	Indicators	Unit of Measurements (Ordinal)*	Source
			[score 6–8 = 3–5 tools]; [score 9–10 = ≥ 6 tools]	
26		Transportation technology	[score 0–2 = None or rental]; [score 3–5 = Two-wheeled vehicle]; [score 6–8 = Three-wheeled vehicle]; [score 9–10 = Four- or six-wheeled vehicle].	Tiasmalomo (2020)
27		Delivery technology	[score 0–3 = Public transportation]; [score 4–7 = Rent]; [score 8–10 = Owned]	Tiasmalomo (2020)
28		Marketing technology (promotion)	[score 0–3 = Conventional]; [score 4–7 = Digital]; [score 8–10 = Conventional and Digital]	Tiasmalomo et al. (2021)

Notes: *primary data.

(units of study with a group of indicators) into larger dimensions. The ALSCAL MDS algorithm then generates unit scores in two dimensions via Equation (2) below (Kavanagh and Pitcher, 2014).

$$\zeta\{S\} = \mathrm{D}^2 + \mathrm{E} \tag{2}$$

ζ describes the monotonic transformation, E is the dual receipt (error) matrix, and D^2 is the *Euclidean* matrix or

$$\mathrm{D}^2 = \sqrt{(y_1 - y_2)^2 + (y_3 - y_4)^2 \ldots} \tag{3}$$

$$\mathrm{D}^2 = \sqrt{\sum_{i=1}^{n} \left(y_i - y_j\right)}\; i \neq j \tag{4}$$

Where, y_i and y_j are the y-coordinates for facilities 1 and 2. Furthermore, the ALSCAL algorithm performs an iteration process to minimize the error E. The RAP-ROSE ordination is plotted on a two-dimensional curve, with only the horizontal line (X-axis) having any significance in the ordination. Meanwhile, the Y-axis only provides variations in indicators and "does not" relate at all to the level of sustainability because the Y-axis is made "*arbitrarily*" (Fauzi, 2019) so that there are only two dimensions, namely "*bad*" and "*good*." The ordination analysis output is also an index value that can be adjusted according to the provisions of Table 3 to determine a study's sustainability status.

3.4.2. Monte Carlo analysis

Monte Carlo analysis detects sources of inaccuracy in the diversity of indicator scores. Errors in indicator scores can occur due to: 1) imperfect knowledge of the unit being analyzed; 2) misunderstanding of the indicator and its score; 3) opinions or judgments between respondents that differ significantly; 4) errors in entering data; 5) the indicator used is not appropriate for the unit being analyzed (Fauzi, 2019).

Table 3
Index value and sustainability status of cut rose farming.

Index Value	Status
0.00–25.00	Unsustainable
25.01–50.00	Less Sustainable
50.01–75.00	Quite Sustainable
75.01–100.00	Sustainable

Source: Adapted from Fauzi (2019).

3.4.3. Leverage analysis

Leverage analysis seeks to discover sensitive factors that affect sustainability coordination. This analysis enables us to observe the shift in ordination (from a poor to a good position) as the indicators are eliminated one by one (Fauzi, 2019). Thus, the indicator's score truly reflects the status of the unit of analysis we are assessing. The sensitive indicator will contribute a score to the sustainability status.

4. Results

4.1. Sustainability of cut rose farming in the ecological dimension

The results of ordination analysis show that of the 14 villages in Batu city, only eight villages have ecological sustainability index values above 50.00, namely Gunungsari village (64.87), Sumbergondo village (61.47), Bulukerto village (60.97), Bumiaji village (58.67), Sumberjo village (57.22), Pandanrejo village (54.91), Sidomulyo village (52.6), and Punten village (51.35), as shown in Fig. 5a. The other six villages, namely Tulungrejo Village (48.63), Temas Village (48.54), Sisir Village (44.04), Dadaprejo Village (43.7), Giripurno Village (40.82), and Junrejo Village (33.08) are classified as "less sustainable". Furthermore, the Monte Carlo analysis results reveal the distribution of minor points that tend to gather and approach the point of the analysis unit, indicating that the RAP-ROSE analysis results in this study are accurate, as seen in Fig. 5b.

The sensitive variables influencing the value of the ecological dimension sustainability index must be known following the inequalities in the situation of each village. According to the results of the leverage analysis, the sensitive indicator that has the greatest impact on ecological sustainability is land elevation (7.24). Then follows chemical fertilizers (6.69) and crop waste management (5.80), as shown in Fig. 6. The ecological dimension sustainability index is calculated using these three sensitive indicators.

4.2. Sustainability status of cut rose farming in the economic dimension

The ordination analysis confirmed that four villages have "sustainable" status in the economic dimension, namely Gunungsari Village (86.23), Sumberjo Village (81.56), Sumbergondo Village (79.34), and Bulukerto Village (75.95), as shown in Fig. 7a. Furthermore, villages with "quite sustainable" status are Bumiaji Village (73.8), Sidomulyo Village (72.89), Pandanrejo Village (69.94), Temas Village (67.73), Tulungrejo Village (65.07), Sisir Village (61.4), Giripurno Village (57.86), and Punten Village (55.13). The villages with the status of "less sustainable" are Junrejo Village (42.59) and Dadaprejo Village (40.10). Subsequently, the Monte Carlo analysis revealed that each research indicator was free of data errors. This is indicated by the distribution of tiny dots that tend to gather and approach the point of the analysis unit, as shown in Fig. 7b.

The difference in the sustainability status of each village above is due to the influence of sensitive indicators with different values. Farm profit (6.41) is the sensitive indicator that has the greatest impact on economic sustainability, as indicated by the leverage analysis. Fig. 8 shows that the market scale (5.36) and market chain (3.69) come next. The magnitude of the value of these three sensitive indicators determines the sustainability status of each village in Batu City.

4.3. Sustainability status of cut rose farming in the social dimension

The results of the ordination analysis reveal that only six villages in Batu City have a "sustainable" status with a social sustainability index

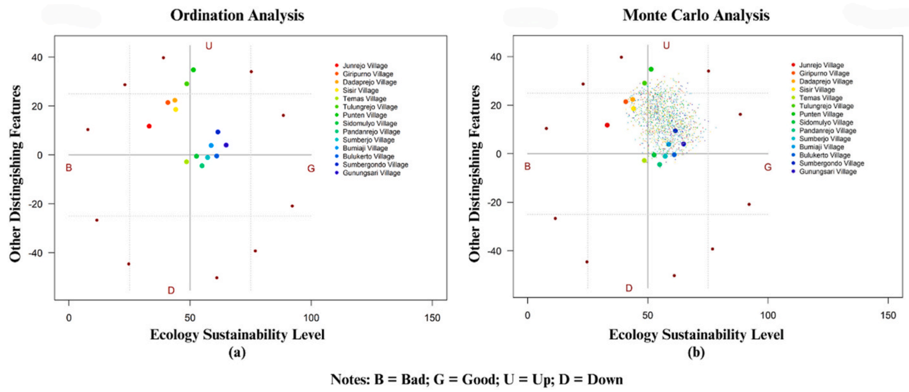

Fig. 5. Results of ordination (a) and Monte Carlo (b) analysis of ecological dimension sustainability.

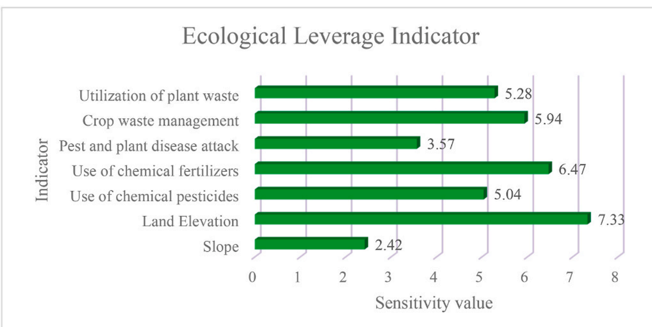

Fig. 6. The leverage analysis results of ecological dimension sustainability.

value above 75.00, namely Gunungsari Village (84.51), Sumbergondo Village (80.72), Bulukerto Village (78.9), Bumiaji Village (78.49), Sumberjo Village (78.3), and Sidomulyo Village (77.07), as shown in Fig. 9a. Meanwhile, the villages with "quite sustainable" status are Pandanrejo Village (74.8), Tulungrejo Village (72.14), Sisir Village (66.96), Temas Village (66.89), Giripurno Village (62.93), Punten Village (60.61), Junrejo Village (60.55), and Dadaprejo Village (58.51). Furthermore, the Monte Carlo analysis results prove that the scatter of minor points tends to cluster and approach the point of the unit of analysis, so there is no error in the RAP-ROSE analysis results as illustrated in Fig. 9b.

The results of the leverage analysis reveal that the most sensitive indicator affecting social sustainability is extension intensity (9.00). This is followed by farming experience (8.45), and family participation in farming (8.13) as shown in Fig. 10. The values of these three sensitive indicators determine the sustainability status of each village in Batu City.

4.4. Sustainability status of cut rose farming in the technology and innovation dimension

The ordination analysis shows that only four villages are classified as “sustainable” with an innovation and technology sustainability index score above 75.00, namely Bumiaji Village (82.27), Gunungsari Village (81.16), Sidomulyo Village (80.77), and Sumbergondo Village (77.11), as shown in Fig. 11a. Then there are villages with a “quite sustainable” status, namely Sumberjo Village (73.23), Pandanrejo Village (70.17), Bulukerto Village (66.51), Tulungrejo Village (54.01), Temas Village (50.47), and Sisir Village (50.08). Finally, the villages with a status of "less sustainable" are Giripurno Village (46.85), Punten Village (42.42), Junrejo Village (39.4), and Dadaprejo Village (37.77). The Monte Carlo analysis findings show a distribution of small points that tend to gather

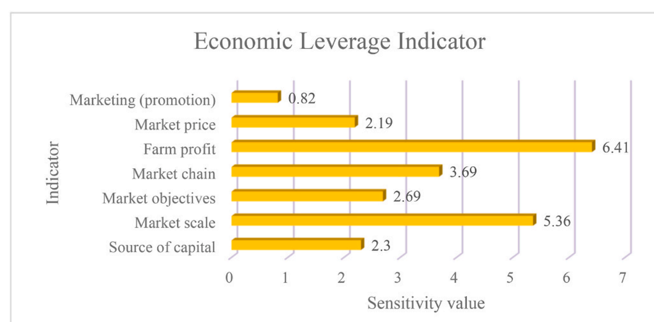

Fig. 8. The leverage analysis results of economic dimension sustainability.

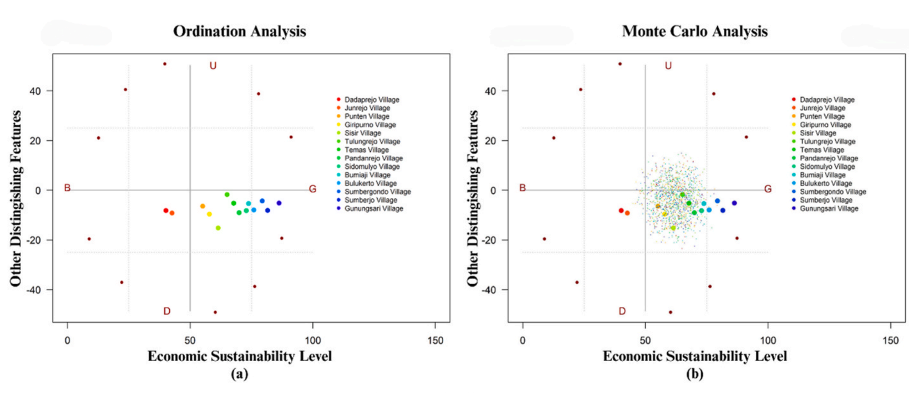

Fig. 7. Results of ordination (a) and Monte Carlo (b) analysis of economic dimension sustainability.

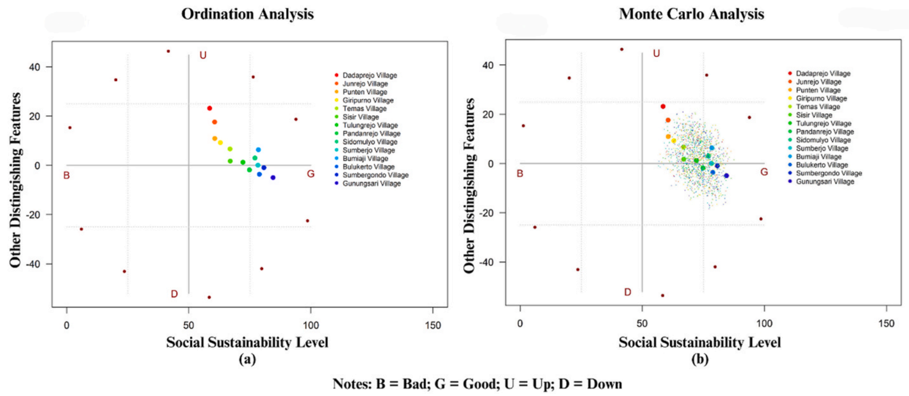

Fig. 9. Results of ordination (a) and Monte Carlo (b) analysis of social dimension sustainability.

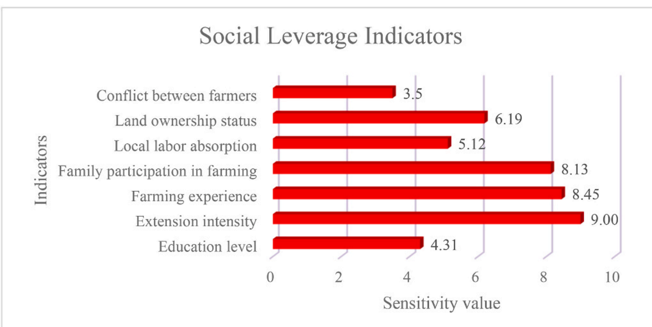

Fig. 10. The leverage analysis results of social dimension sustainability.

and approach the analysis unit, indicating that the RAP-ROSE analysis results are genuine, as illustrated in Fig. 11b.

Sensitive indicators influence the sustainability status of each village, which varies in value. The results of the leverage analysis indicate that transportation technology (2.74) is the most sensitive indicator influencing the sustainability of technology and innovation. Furthermore, the adoption of environmentally friendly cultivation innovations (2.46) and marketing technology (2.03) are the two essential factors, as shown in Fig. 12. The magnitude of the value of these three sensitive indicators greatly determines the sustainability status of each village in Batu City.

4.5. Sustainability of multidimensional cut rose farming

The sustainability analysis results show that the cut rose farming business in Batu City is "quite sustainable" with an average score of 62.57. The average score for each dimension is 51.49 (ecological dimension), 66.40 (economic dimension), 71.53 (social dimension), and 60.87 (technology and innovation dimension), as shown in Table 4. The social dimension has the highest average score among all dimensions. Meanwhile, the ecological dimension has the lowest average score.

Based on the results of the multidimensional sustainability analysis above, a visual comparison of the values between dimensions can be seen in Fig. 13.

5. Discussions

The ecological sustainability status of eight villages (Gunungsari Village, Sumbergondo Village, Bulukerto Village, Bumiaji Village, Sumberjo Village, Pandanrejo Village, Sidomulyo Village, Punten Village) in Batu City is "quite sustainable" (Fig. 5a). This "quite

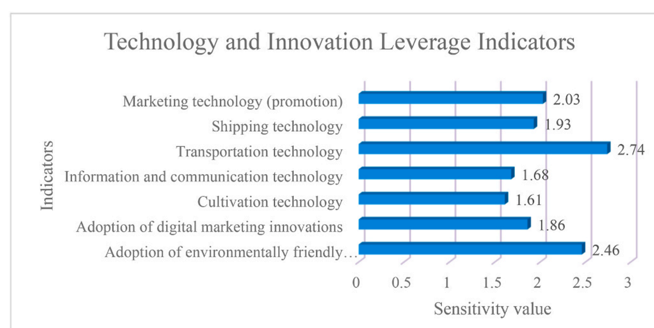

Fig. 12. The leverage analysis results of the technology and innovation dimension.

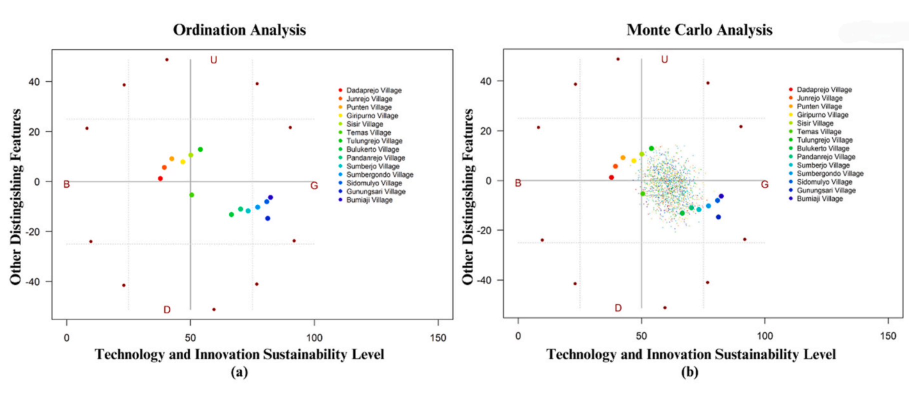

Fig. 11. Results of ordination (a) and Monte Carlo (b) analysis of the sustainability of technology and innovation dimensions.

Table 4
Sustainability of cut rose farming in Batu City.

Village Names	Dimensions			
	Ecology	Economic	Social	Technology and Innovation
Sumberjo	57.22	81.56	78.30	73.23
Sisir	44.04	61.40	66.96	50.08
Sidomulyo	52.60	72.89	77.07	80.77
Temas	48.54	67.73	66.89	50.47
Giripurno	40.82	57.86	62.93	46.85
Pandanrejo	54.91	69.94	74.80	70.17
Bumiaji	58.67	73.80	78.49	82.27
Bulukerto	60.97	75.95	78.90	66.51
Punten	51.35	55.13	60.61	42.42
Tulungrejo	48.63	65.07	72.14	54.01
Sumbergondo	61.47	79.34	80.72	77.11
Gunungsari	64.87	86.23	84.51	81.16
Junrejo	33.08	42.59	60.55	39.40
Dadaprejo	43.70	40.10	58.51	37.77
Average	**51.49**	**66.40**	**71.53**	**60.87**
Multidimensional Average				**62.57**

sustainable" status indicates that the cut rose farming in these villages has a sufficiently long lifespan to be viable. However, the current suboptimal results serve as a benchmark for improving the sustainability status of cut rose farming to a higher level, namely "sustainable," so that cut rose farming can continue indefinitely without time constraints. Additionally, six other villages (Tulungrejo Village, Temas Village, Sisir Village, Dadaprejo Village, Giripurno Village, and Junrejo Village) have a "less sustainable" status, requiring more intensive efforts to elevate their status to "sustainable." Efforts to improve the ecological sustainability of cut rose farming include improving sensitive indicators that still do not meet ideal criteria. The indicator considered to be the least compliant with the ideal criteria for ecological sustainability is slope gradient (Fig. 6). Batu City is a hilly and mountainous area with steep land characteristics, which is a significant problem. Slope gradient is the main limiting factor affecting plant growth and production (Andrian et al., 2014). Steep land slopes and high rainfall will result in more significant erosion, so that crop production will decrease. Highland areas generally have land slopes >15 %. Agricultural land on a slope of 15–40 % is an area that is prone to landslides. Sihite (Sihite et al., 2015) explained that the greater the percentage of slope, the greater the level of erosion produced. Sloping land has the potential for erosion, resulting in soil damage such as decreased soil organic matter content, reduced nutrient content, and reduced soil water availability for plants. Arvi (Arvi et al., 2019) also stated that the steeper the slope, the greater the erosion risk. Of course, due to this erosion, the top layer of soil (topsoil) will be eroded, affecting soil depth and fertility. The slope is closely related to the soil's nutrient availability condition. Steep slopes require special methods to prevent erosion so that cut rose production can be optimized. The methods that can be used include vegetative methods (contour strip cropping, buffering, cover crops), mechanical methods (terracing, contour tillage, gully ditches), and chemical methods (soil conditioners). Furthermore, the indicator considered to best meet the ideal criteria for ecological sustainability in Batu City is land elevation. Almost all villages in Batu City are located in highland areas, with an average altitude of 900 m above sea level, which follows the optimal growth requirements of rose plants. In line with the opinion of Sylviana (Sylviana et al., 2019) that rose plants can grow optimally in the highlands, namely >900 masl. This is undoubtedly a supporting factor in the sustainability of the ecological dimension. Land elevation can trigger environmental conditions (Aryani et al., 2022). Different land elevations will cause differences in microclimate and overall weather, affecting plant growth and crop production (Andrian et al., 2014). Differences in microclimate conditions can be in temperature, humidity, and light intensity (Arvi et al., 2019).

The villages that have a "sustainable" status in the economic dimension are Gunungsari Village, Sumberjo Village, Sumbergondo Village, and Bulukerto Village, as shown in Fig. 7a. The "sustainable" status indicates that the cut rose farming business in these four villages can run continuously in the long term, so this status needs to be maintained. Furthermore, the villages with a "quite sustainable" status are Bumiaji Village, Sidomulyo Village, Pandanrejo Village, Temas Village, Tulungrejo Village, Sisir Village, Giripurno Village, and Punten Village. This "quite sustainable" status indicates that the cut rose gardens in each village have a sufficiently long time to continue being cultivated. However, this "quite sustainable" status must be upgraded to "sustainable." The villages with a "less sustainable" status are Junrejo Village and Dadaprejo Village, so the sustainability of these two villages is at risk because the farming projections are expected not to last long, especially in the economic dimension. The way to improve the economic sustainability of cut rose farming is to improve the sensitive indicators that still do not meet the ideal criteria. The indicator that is believed to not yet meet the ideal criteria for economic sustainability is marketing (promotion) (Fig. 8). Cut rose flower farmers in the city generally have not maximized marketing for their cut rose flower crops. This is due to farmers' limited knowledge and ability to market their products effectively, particularly in digital marketing. The cut rose farmers in the city depend on local middlemen to sell the harvest more quickly and reduce the risk of damaged cut roses. Compared to the price directly to consumers, the price received is much higher and more profitable. Today, marketing strategies are becoming increasingly modern, primarily by

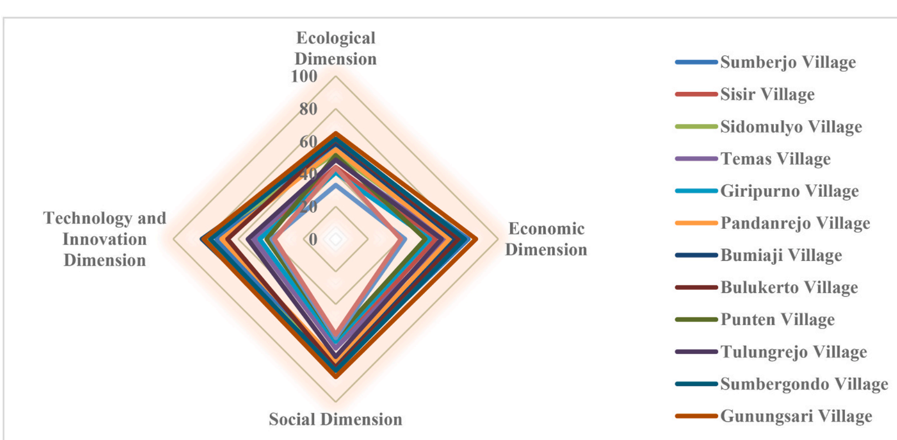

Fig. 13. Kite diagram of the sustainability of cut rose farming in Batu City.

leveraging internet technology known as digital marketing. Therefore, cut rose farmers can utilize digital marketing as a promotional strategy to increase market demand and sales volume of their products. In addition, digital marketing can foster customer loyalty to cut roses because digital marketing facilitates communication with customers and meets all customer needs (Purwana et al., 2017), (Zhu and Chen, 2015). Meanwhile, farm profits are considered the most appropriate indicator of ideal criteria for economic sustainability. Cut rose farmers in Batu City have been running their farms quite well. All cut rose farmers recognize that their farms have been profitable. According to Sudaryono (Sudaryono and Manajemen pemasaran, 2016) an activity carried out by every business actor aims to make a profit. Nurawaliah (Nurawaliah et al., 2020) added that the purpose of every business is to get the maximum profit.

In terms of social sustainability, only six villages in Batu City have been designated as “sustainable,” namely Gunungsari Village, Sumbergondo Village, Bulukerto Village, Bumiaji Village, Sumberjo Village, and Sidomulyo Village (Fig. 9a). Meanwhile, the villages with "quite sustainable" status are Pandanrejo Village, Tulungrejo Village, Sisir Village, Temas Village, Giripurno Village, Punten Village, Junrejo Village, and Dadaprejo Village. Consequently, it is imperative to enhance the social sustainability of cut rose farming by enhancing sensitive indicators that do not presently meet the ideal criteria. The indicator considered the least fulfilling of the ideal social dimension sustainability criteria is the conflict between farmers (Fig. 10). Although cut rose flower farmers in Batu City have a high level of solidarity, it cannot be denied that conflicts arise during the buying and selling of crops. In this case, the actors in question were farmers who sold crops and served as middlemen traders. Buying and selling do not go well in cut-rise transactions when the seller asks for a slightly higher price while the trader sets a standard price. Gunungsari Makmur (gumur) is the name of the Farmers’ Group Association (gapoktan) located in Gunungsari Village, Bumiaji, Batu City. Gapoktan "gumur" is a forum that builds rose farmers’ solidarity to achieve their goals (Setiawan and Pratiwi, 2021). Solidarity within the organization leads to effective and efficient performance in achieving collective goals. At the same time, the indicator considered to meet the ideal criteria for the sustainability of the social dimension is the intensity of counseling. Field Agricultural Extension Workers in Batu City continue actively conducting extension activities. Routine extension activities are carried out monthly to increase their intensity. Agricultural extension personnel must have agricultural expertise to guide farmers (Jamil et al., 2021). In particular, the role of agricultural extension is to facilitate the adoption of technology and provide field knowledge so that farmers can increase their productivity (Sumo et al., 2022). Furthermore, the role directs farmers to accept new technologies and utilize agricultural inputs optimally (Wossen et al., 2017), (Yuniarsih et al., 2024).

We found only four villages with “sustainable” status for the dimension of innovation and technology, namely Bumiaji Village, Gunungsari Village, Sidomulyo Village, and Sumbergondo Village, as shown in Fig. 11a. Then there are villages with a “quite sustainable” status, namely Sumberjo Village, Pandanrejo Village, Bulukerto Village, Tulungrejo Village, Temas Village, and Sisir Village, Finally, the villages with a status of "less sustainable" are Giripurno Village, Punten Village, Junrejo Village, and Dadaprejo Village. As a result, it is essential to improve the sustainability of innovation and technology in cut rose farming by improving sensitive indicators that do not currently satisfy the ideal criteria. The indicator considered the least fulfilling of the ideal criteria for the sustainability of the technology and innovation dimension is cultivation technology (Fig. 12). Almost all cut rose flower farmers still use conventional cultivation tools. Farmers feel they do not need these modern tools, and there is not enough capital to switch to using more modern cultivation technology. Mottaleb (2018) explains that agricultural development must transform from a traditionally oriented rural culture towards acceptance and dependence on science and technology, primarily by adopting better, scale-appropriate, and environmentally friendly technologies. Therefore, farmers must embrace technology to increase the production of cut roses. The adoption of new agricultural technologies is a prerequisite for sustainable increases in agricultural production and productivity levels (Massresha et al., 2021). The level of adoption of modern cultivation technology is influenced by several factors such as age, income, education level, farming experience, and family size (Binh, 2022), (Dhraief et al., 2019), (Li et al., 2020). The indicator that meets the ideal criteria for the sustainability of the technology and innovation dimension is transportation technology. This result is in line with the results of research Warti (2017), that transportation is one of the links in post-harvest handling. Generally, cut rose farmers in the research area already have private vehicles to transport their crops to the harvest storage area. The usual vehicles used by farmers are motorcycles and pick-up trucks. The quality of cut flowers is influenced by postharvest handling, especially during transportation. Post-harvest handling of cut flowers needs to be considered so that the quality can be maintained during transportation. The right transportation tool not only facilitates the movement of goods but must be able to keep the harvest from mechanical disturbances during transportation. The percentage of damage to horticultural products such as vegetables, fruits, and cut flowers can reach 30–50 % if postharvest handling is not done properly (Rozana et al., 2021).

Generally, rose farming in Batu City is "quite sustainable" with an average value of 62.57 (Table 4). This "quite sustainable" status indicates that cut rose farming in this region has a long enough period to continue to be cultivated. However, it is necessary to increase its status to "sustainable" so that cut rose farming continues to exist and develop indefinitely. Gunungsari Village is the most outstanding village in the following three dimensions: 1) ecology, 2) economy, 3) social. It has been proven that this village is the highest producer of cut roses in Batu City (Wahyudi et al., 2022). The production of cut roses in Gunungsari Village in 2023 reached 67,017,020 stems/year (Dinas Pertanian dan Ketahanan Pangan Kota Batu, 2024). This indicates that Gunungsari Village has significant potential as a region for the development of cut roses in Indonesia (Puspasari et al., 2017). This also constitutes a highly valuable contribution to the demand for cut roses in Indonesia. Meanwhile, Bumiaji Village excels only in the technology and innovation dimension. Next, Dadaprejo Village has the lowest score in all three dimensions: 1) economy, 2) social, 3) technology and innovation. Finally, Junrejo Village has the lowest score in the ecological dimension.

Visually, we observe that the ecological dimension is at the lowest level of achievement among the other dimensions. This indicates weak and lagging characteristics that need to be seriously improved (Fig. 13). However, the different dimensions also need to be enhanced to achieve “sustainable” status. Therefore, it is essential to focus on sensitive indicators to ensure that the cut rose flower farming industry in Batu City achieves “sustainable” status. As a result, this study on cut rose flowers using the Multidimensional Scaling (MDS) analysis approach is considered highly suitable and adequate for enhancing the sustainability status of the cut rose flower farming industry in Batu City. The results of this analysis serve as a rational and logical reference and evaluation tool.

6. Conclusions and limitations of the study

This study aimed to analyze the sustainability status of cut rose flower farming and sensitive indicators that affect its sustainability. The results showed that cut rose farming in Batu City is "quite sustainable" with an average value of 62.57. This suggests that cut rose farming in this city has a sufficient period to continue cultivation. However, increasing its status to "sustainable" is necessary so that cut rose farming in Batu City continues to exist and develop indefinitely. The average value of each dimension of sustainability of rose farming in Batu City is the ecological dimension (51.49), economic dimension (66.40), social dimension (71.53), and technology and innovation dimension (60.87). Based on the data and facts we found, it is recommended to improve the sustainability status of cut rose farming by dealing with sensitive indicators that still do not meet the ideal criteria, namely, steep land slopes, lack of marketing (promotion), frequent conflicts between farmers, and minimal use of cultivation technology. Overall, the sustainability of rose farming in Batu City is highly dependent on implementing innovative and sustainable agricultural practices, as well as support from various parties, especially the government, to overcome existing challenges and capitalize on available opportunities. Some forms of support that the government can provide include: 1) financial assistance in the form of capital; 2) fertilizer and pesticide subsidies; 3) establishment of a special institution as a mediation forum for farmers; 4) infrastructure development for farmer mobility in cultivating and marketing cut roses; 5) provision of technology and information; 6) promotion of cut roses on the international market. Our research has limitations in terms of the number of dimensions explored. This study only examines four dimensions, namely 1) ecology, 2) economy, 3) society, and 4) technology and innovation. Therefore, further research needs to adopt and explore other dimensions that are more relevant to the issues currently being faced. The more dimensions that are adopted and explored, the more comprehensive and in-depth the understanding of the phenomenon becomes. This naturally provides a more complete picture by considering various perspectives or aspects.

7. Recommendations

Based on our findings, we have summarized several important recommendations related to slope, marketing (promotion), conflicts between farmers, and cultivation technology. Steep land requires unique methods to prevent erosion and optimize the production of cut roses. The methods that can be taken are vegetative methods (contour strip cropping, buffering, cover crop), mechanical methods (terracing, contour tillage, mounds), and chemical methods (soil conditioner). The lack of marketing (promotion) is due to farmers' lack of knowledge and ability. So this cannot be separated from the role of local agricultural extension officers as facilitators to train farmers to master digital and conventional marketing (promotion) methods. Conflicts between farmers require strengthening solidarity through the Farmer Group Association (gapoktan), as one of the objectives of forming a gapoktan is to enhance solidarity among farmers, thereby fostering closer cooperation to achieve common goals. The lack of use of cultivation technology is caused by limited capital. Capital is the main factor that prevents farmers from adopting current cultivation technologies. Therefore, government support is needed to provide subsidies, capital assistance, and easily accessible farm credit.

CRediT authorship contribution statement

Riska Tiasmalomo: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Muslim Salam:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. **Hari Iswoyo:** Writing – review & editing, Writing – original draft, Validation, Methodology, Conceptualization. **Muhammad Hatta Jamil:** Writing – review & editing, Validation, Resources, Methodology, Formal analysis. **A. Nixia Tenriawaru:** Writing – review & editing, Validation, Resources, Methodology, Formal analysis. **Rahmansyah Dermawan:** Writing – review & editing, Validation, Supervision, Methodology, Formal analysis. **Nitty Hirawaty Kamarulzaman:** Writing – review & editing, Methodology, Formal analysis. **Akhsan:** Writing – review & editing, Resources, Methodology, Formal analysis. **Heliawaty:** Writing – review & editing, Validation, Resources, Methodology, Funding acquisition. **Letty Fudjaja:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis. **Rahmadanih:** Writing – review & editing, Validation, Methodology, Funding acquisition. **Muhammad Ridwan:** Writing – review & editing, Methodology, Funding acquisition, Formal analysis. **Hamed Noralla Bakheet Ali:** Writing – review & editing, Validation, Methodology, Formal analysis. **Siti Hardiyanti Syam:** Writing – review & editing, Validation, Methodology. **Ridha Anugerah Putra:** Writing – review & editing, Validation, Resources, Methodology.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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