Exploring the measurements of COVID-19-induced supply chain disruptions and their implications on the economic vulnerability of small-scale farmers

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Abstract

Purpose – The main aim of this study is to explore the appropriate factors in measuring COVID-19-induced supply chain disruptions and the impact of these disruptions on the economic vulnerability of small-scale farmers in Sri Lanka.

Findings – The findings revealed that most of the farmers have continued to cultivate even during the pandemic despite several challenges which affected their economic status. Therefore, it is concluded that COVID-19-induced transportation and demand disruptions exacerbated the economic vulnerability of small-scale farmers over the disruptions in supply and production.

Practical implications – The findings of this study are crucial for formulating novel policies to improve the sustainability of the Sri Lankan agricultural sector and alleviate the poverty level of Agri-communities in the countryside. As farming is a vital sector in the economy, increased attention ought to be given on facilitating farmers with government-encouraged loans or allowances for their financial stability. Further, the respective government authorities should develop programs for importing and distributing adequate quantities of fertilizers among all the farmers at controlled prices so that they can continue their operations without any interruption. Moreover, the government could engage in collaboratively work with private organizations to streamline the Agri-input supply process. There should be a government initiative for critical consideration of the issues of farming families and their continued motivation to engage in agriculture. Thus, farmers' livelihoods and agricultural prosperity could be upgraded through alternative Agri-inputs and marketing strategies, providing financial assistance, encouraging innovative technology, etc.

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Ethics statement: Since this research study focused solely on human attitudes and conduct, the relevant ethical considerations were applied honestly during the research procedure including (a) get informed consent from potential research subjects; (b) reduce the risk of harm to participants; (c) safeguard their anonymity and confidentiality; (d) prevent deceptive methods; and (e) provide people with the option to withdraw from the study.

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Originality/value – Despite the significance and vulnerability of the vegetable and fruit sector in Sri Lanka, there is a limitation in the empirical studies conducted on the supply chain disruptions caused by COVID-19 measures and their implications on the farmers' livelihood. Furthermore, previous empirical research has not employed adequate quantitative tools to analyze the situation or appropriate variables in evaluating COVID-19-induced disruptions. Hence, the current study explored the appropriate factors for measuring COVID-19-induced supply chain disruption using exploratory factor analysis. Then, the impact of those factors on the economic vulnerability of the small scale farmers was revealed through the ordinal logistics regression analysis.

Keywords COVID-19, Supply chain disruptions, Economic vulnerability, Vegetable and fruit supply chains, Small-scale farmers

Paper type Research paper

1. Introduction

The COVID-19 pandemic has disoriented the global supply chains, serving as a new catalyst for global supply chain disruptions. The global pandemic has had a significant impact on all the facets of society and the economy, forcing researchers and experts to make a variety of completely novel decisions and policy-making settings (Aday and Aday, 2020; Husain Arif *et al.*, 2020). COVID-19 has a dramatic disruption in many economic sectors, with some challenging repercussions. The primary cause of the food supply chain collapse during the crisis was a breakdown in the Agri-food supply chain's producer- end due to input and labor shortages, transportation issues, and delays (Aday and Aday, 2020). Vegetables and fruit supply chains have dominated the Sri Lankan agricultural sector as they provide a significant source of income for many farming communities (Rathnayake *et al.*, 2022). Moreover, vegetable and fruit cultivators in Sri Lanka have usually been more economically vulnerable than the other farmers due to a lack of a guaranteed price for their products, limited access to reliable information sources, higher transaction costs in marketing, and a lack of input subsidies (Rathnayake *et al.*, 2022). If the supply chain is disrupted, managing fruits and vegetables becomes difficult due to their perishability and difficulty in handling them once harvested. In Sri Lanka, the private sector dominates the marketing of these perishable goods, with intermediaries playing an important role. However, the profit margins of farmers for vegetable and fruit sales are comparatively low and prone to fluctuate, due to the intermediaries and the lack of guaranteed prices (Rathnayake *et al.*, 2022). As a result, these vegetable and fruit farmers may be more vulnerable to damage than other types of farmers.

As per the literature review, it can be revealed that the COVID-19 pandemic-induced disruptions in vegetable and fruit supply chains as well as its impact on the economic vulnerability of vegetable and fruit farmers in Sri Lanka have not been adequately explored using supply chain disruptions and economic vulnerability related concepts and theories. Despite the importance and exposure to the nature of Sri Lanka's vegetable and fruit sectors, limited empirical studies have been conducted on the impact of COVID-19 measures on the livelihoods of small-scale farmers, while qualitative approaches have been applied in many of the studies (Galappattige, 2020; Rathnayake *et al.*, 2022; Roshana and Hassan, 2020). Although Rathnayake *et al.* (2022) explored the impact of COVID-19 mitigation strategies on vegetable farmers' production, marketing, and income level in the upcountry region, this study is based on qualitative data collected from only two districts. Hence, there is a lack of empirical studies in this domain which uses a quantitative approach along with advanced statistical tools. Although a few studies has been published regarding the economic impact of COVID 19 recently (Central Bank of Sri Lanka, 2020; ICRA Lanka, 2020; Rathnayake *et al.*, 2022), there is a lack of empirical studies conducted in examining the economic vulnerability caused by the pandemic specially in the vegetable and fruit supply chain in Sri Lanka. Therefore, this current study expects to fill this methodological gap and empirical gap that exists in the literature in Sri Lankan context.

Since COVID-19 is a novel phenomenon that has significantly disrupted most of the global food supply chains, it is comparatively challenging for scholars to identify the most appropriate factors in measuring COVID-19-induced disruptions. Hence, the current study explored the appropriate factors in measuring COVID-19-induced supply chain disruptions using exploratory factor analysis. Then, the impact of those factors on the economic vulnerability of the small-scale farmers has been revealed through the ordinal logistics regression analysis technique. Therefore, the main objectives of this study are to identify the most appropriate factors in measuring COVID-19-induced disruptions and to examine the impact of those COVID-19-induced supply chain disruptions on the economic vulnerability of small-scale farmers in Sri Lanka. This study mainly contributed to the crisis management literature by identifying the appropriate factors in measuring the impact of a crisis like COVID-19. The findings of this study will be significant for formulating novel policies to improve the sustainability of the agricultural sector and to alleviate the poverty level of Agri-communities in the countryside. Furthermore, the outcomes of this study will help stakeholders in the vegetable and fruit supply chains in realizing the actual impact of the pandemic on their industry and the potential for small-scale business expansion and sustainability. Further, it will also propel them to new heights in terms of profit margins and overall well-being.

The rest of the paper is structured as follows: Section 2 presents the summary of the literature review, Section 3 describes the methodology used in the study, Section 4 presents the results of the analysis and Section 5 and Section 6 provide the discussion and conclusion, respectively.

2. Literature review

2.1 Vegetable and fruit supply chains in Sri Lanka

Agriculture makes a significant contribution to the national economy, food security, and employment in Sri Lanka. It accounts for less than 10% of the national output while employing more than one-third of the labor force (ICRA Lanka, 2020). Vegetable and fruit supply chains have dominated the Sri Lankan agricultural sector as a significant source of revenue for farming communities. The agricultural production index remained relatively stable in 2019 due to significant drivers such as oleaginous fruit output (Gunawardana, 2020). The productive tropical climate and the terrain conditions suit a variety of crops; therefore, a variety of tropical fruits and vegetables is delivered for domestic consumption and export in Sri Lanka. Further, approximately eighty different fruit and vegetable species are grown by autonomous farmer clusters across various agro-climatic zones in Sri Lanka. These farmers produce over 900,000 metric tons of fruit and vegetables each year, which they export to a variety of international destinations, both fresh and processed (Sri Lanka Export Development Board, 2022). The supply base of the vegetable and fruit supply chains is comprised of small farms and home gardens, cluster organizations/commercial farms, Agro zone projects and integrated agriculture projects, village/central collecting centers, and provincial wholesale markets comprise (Sri Lanka Export Development Board, 2022).

2.2 Supply chain disruptions

"A supply chain disruption is an unexpected event that stops or slows the normal flow of material with potentially negative consequences to supply chain members" (Scheibe and Blackhurst, 2018, p. 1). The spread of disruptions may have an impact on supply chain performance, including delays in manufacturing or logistical processes, demand-supply mismatches, and potential financial losses. These are essentially undesirable circumstances that frequently involve upstream supply issues and result in network failures (Macdonald *et al.*, 2018). Natural disasters, pandemics, and economic crises have caused supply chain disruptions, prompting researchers to investigate system robustness at both the company

and network levels. Thus, Supply chain disruptions can be divided into four main categories: (1) disruption in supply, (2) disruption in production, (3) disruption in transportation, and (4) fluctuation in demand. Initially, a supply disruption is defined as any interruption in the material supply caused by a delay, unavailability, or any other type of disturbance (Paul *et al.*, 2015). Then, a production disruption can be defined as any type of interruption in production that is caused by a shortage of materials, machine breakdown, unavailability, or any other type of disturbance (Paul *et al.*, 2015). Next, a transportation disruption is defined as any type of disruption in the transportation system caused by vehicles breakdown, road work, strikes, and natural disasters such as floods and earthquakes (Paul *et al.*, 2015). Finally, a demand disruption is defined as any variation in product demand that can be increased or decreased for a certain period (Paul *et al.*, 2015).

2.3 COVID-19 pandemic-induced supply disruptions in food supply chains

Farm labor, seeds, pesticides, fertilizers, and energy are the main inputs for farm production. Agricultural production supplies were disrupted to varying degrees during the epidemic. Labor shortages have primarily hampered farm production. While some agricultural sectors, such as vegetables and fruits, rely heavily on labor, grains, and oilseeds require less. Due to restrictions on people's mobility, the availability of seasonal workers for fruit and vegetable cultivation and harvesting has been limited in several countries (Deconinck *et al.*, 2020). While there were no shortages of seeds during this period, farmers had some difficulty in obtaining them due to travel and import restrictions (Deconinck *et al.*, 2020). China is a significant supplier of pesticides, which was initially a source of concern. These concerns seemed to vanish when China was lifted from its state of emergency (Aday and Aday, 2020). Also, fertilizer availability was not a major issue on a global scale, but local disruptions occurred because of travel restrictions (Aday and Aday, 2020). Even though the majority of agricultural firms rely on their core inputs, they are more vulnerable to supply disruptions because they must source their supplies from domestic markets.

2.4 COVID-19 pandemic-induced production disruptions in food supply chains

Due to the limited access to agricultural supplies by farmers, some agricultural lands remained uncultivated. However, because agricultural farms were typically located in remote areas away from densely populated areas, the pandemic had a limited impact on rural agricultural production. On the contrary, COVID-19 completely disturbed the food processing industry through the laws of social distancing, medical leave, and lockdown procedures that were designed for epidemic control (Aday and Aday, 2020; Deconinck *et al.*, 2020; Michele, 2020). Although centralized food manufacturing aided food processors in increasing production and lowering costs, it disrupted the food chain during the epidemic outbreak because of factory closures, leaving high-capacity production lines at lower levels of productivity (Aday and Aday, 2020). The closure of those food facilities reverberated throughout the food supply chain, slowing the distribution of food products and agricultural inputs and causing problems in consistent supply of food to the markets (Deconinck *et al.*, 2020). COVID-19's long-term containment strategies destroyed the food production efficiency and effectiveness, and the availability of staple foods and nutrition.

2.5 COVID-19 pandemic-induced transportation disruptions in food supply chains

The prominent issues in the food supply chain during the global crisis were obtaining raw materials from suppliers and ensuring the smooth flow of food from producers to end customers. While agricultural activities were in continuation throughout the pandemic, transportation and logistical bottlenecks slowed the movement of goods along supply chains

(World Bank, 2021). COVID-19 influenced the modes of transportation in a variety of ways. While Bulk shipments experienced no significant delays, the air freight system was considerably affected (Michele, 2020). The delivery of staple foods was obstructed because of the restrictions between cities, provinces, regions, and countries. The supply of perishable high-value goods, such as vegetables and fruits, was severely disrupted by these logistics issues and border inspection delays that disorientated the whole food supply networks (Aday and Aday, 2020). Furthermore, most of the fresh food items from restaurants and food processing facilities were destroyed in vain owing to transit complications that occurred during the lockdown and shutdown of institutions (Michele, 2020).

2.6 COVID-19 pandemic-induced demand disruptions in food supply chains

In considering the impact of the COVID-19 pandemic on consumers' food demand, it is evident that the demand differs on factors such as food price, income level, socio-demographic status, consumption, shopping preferences, and time restrictions (Aday and Aday, 2020; Husain Arif *et al.*, 2020; Barman *et al.*, 2021; Godrich *et al.*, 2022). Changing demands required changes in packing materials and their design, delivery services, and storage requirements (Godrich *et al.*, 2022). At the inception of the global crisis itself, consumer demand for several food items had risen, and some shop shelves had been momentarily emptied, causing an excess sale of vital goods and a massive surge in food prices (Aday and Aday, 2020; Godrich *et al.*, 2022). As a result of their desire to eat healthier meals while staying within their budget, consumers have turned to natural food and beverage items that comprised ingredients that provide nutritious, such as vegetables, fruits, whole grains, olive oil, etc. (Aday and Aday, 2020; Lambert *et al.*, 2021). Due to panic buying and unnecessary storing of food, demand for vital food products surged considerably as the epidemic spread, restraining access to essential food items for vulnerable segments of the population (Alsuwailem *et al.*, 2021; Deconinck *et al.*, 2020; Central Bank of Sri Lanka, 2020; Institute of Policy Studies, 2020).

2.7 COVID-19- induced economic vulnerability of small-scale farmers in the vegetable and fruit supply chains

Agriculture-based economies were significantly affected by COVID-19, resulting in food security challenges such as inflation, price volatility, and lack of traceability (Barman *et al.*, 2021; Joshi and Sharma, 2021; Lambert *et al.*, 2021). Agriculture is the primary source of income for a substantial section of the population in developing countries. Many sectors in agriculture were already vulnerable to a variety of disturbances and pressures, including climate change, market failure, and pest and disease outbreaks. As a result, agricultural sectors in most of the developing countries were susceptible to the epidemic (Hossain, 2020). Food export and import break, economic crisis, break in agriculture sector development, the bankruptcy of enterprises, loss of income, unemployment, poverty, and inequality are considered the economic risks of COVID-19 for agricultural systems (Streimikienė *et al.*, 2022).

Sri Lanka, like many other emerging countries, was no exception. For many Sri Lankan farming households, the vegetable sector is a vital source of income (Rathnayake *et al.*, 2022). The COVID-19 mitigating measures resulted in market closures, reduced demand for farm produce, agricultural input shortages, and labor availability issues (Galappattige, 2020; Hossain, 2020; Roshana and Hassan, 2020). Consequently, the income and purchasing power of farmers decreased, making farming families economically vulnerable. According to the studies conducted in India and Bangladesh, farmers who produced perishable products, such as vegetables and fruits, were severely impacted by COVID-19 (Mottaleb *et al.*, 2020; Rathnayake *et al.*, 2022). Farmers who produced perishable products, such as vegetables and fruits, lost access to traditional markets, leaving them with the limited choice of destroying

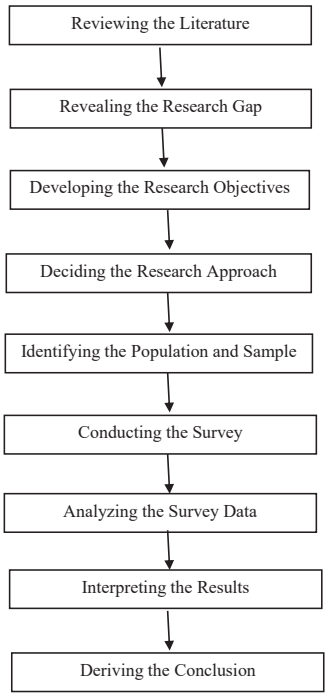
the unsold produce. Many small-scale farmers in developing nations, like Sri Lanka, are struggling to remain economically viable and poor. The effects of the governmental COVID-19 mitigation strategies on farmers' livelihoods might harm the countries to meet their poverty-eradication strategies in the long run.

3. Methodology

3.1 Research approach

The main objective of this study was to examine the impact of COVID-19-induced disruptions in the vegetable and fruit supply chains on the economic vulnerability of small-scale farmers in Sri Lanka. The following flow chart (Figure 1) illustrates the stages that the research went through to achieve this research objective.

A deductive research approach was mainly followed in this current study. As explained in the literature review, Supply chain disruptions can be divided into four main categories: (1) disruption in supply, (2) disruption in production, (3) disruption in transportation, and (4) fluctuation in demand. In the operationalization (see Table 1), these four categories: "Supply Disruption (SD)", "Production Disruption (PD)", Transportation Disruption (TD)" and "Demand Disruption (DD)", are considered the independent variables. Supply disruptions are measured through the measurement items: SD1, SD2, SD3, SD4, and SD5, Production disruptions are measured through the measurement items: PD1, PD2, PD3, PD4 and PD5, Transportation Disruptions (TD) are measured through the measurement items: TD1 and TD2 and Demand Disruptions (DD) are measured through the measurement items: DD1, DD2, DD3 and DD4.



Source(s): Authors' own work

Figure 1.
Flow Chart of the Research Design

Constructs	Description	Measurement items	Sources
Supply Disruption (SD)	Any form of interruption in the material supply that may be caused due to delay, unavailability, or any other form of disturbance (Paul *et al.*, 2015)	SD1 – We experienced supply failures that affect production SD2 – We experienced extended lead time at the supplier's end SD3 – There was a change in the price of raw materials SD4 – There was a change in the quality of raw materials supplied SD5 – A key supplier has gone out of business	Udofia *et al.* (2021)
Production Disruption (PD)	Any form of interruption in production that may be caused due to shortage of material, machine breakdown, unavailability, or any other form of disturbance (Paul *et al.*, 2015)	PD1 – There was a reduction, suspension, or temporary discontinuation of the Production activities PD2 – There was a change in the cultivation cost PD3 – There was a change in the number of crop yields PD4 – There was a change in the quality of crop yields PD5 – There was an unavailability of labor	Frizelle *et al.* (1998)
Transportation Disruption (TD)	Any form of interruption in the transportation system that may be caused due to vehicle breakdowns, road work, strikes, and natural disasters like floods and earthquakes (Paul *et al.*, 2015)	TD1 – There were transportation interruptions in getting the Agri-Inputs from suppliers TD2 – There were transportation interruptions in providing the production outputs for traders/ economic centers	Wilson (2007)
Demand Disruption	Any kind of variation in product demand at the retailer end. Demand can be increased or decreased for a certain period	DD1 – There was a change in the quantity demanded by the customers DD2 – There were any delays in finished goods (vegetables and fruits) deliveries DD3 – There was a change in the number of products disposed	Frizelle *et al.* (1998)
		DD4 – There was a change in the prices of products sold to the customers	Rahman *et al.* (2022)
Economic Vulnerability	"Economic vulnerability relates to the losses in economic assets and processes of agricultural systems" (Streimikienė *et al.*, 2022)	The relative distance of the monthly average income from the minimum wage	Sneessens *et al.* (2019)

Source(s): Authors' own work

Table 1.
Operationalization

According to the literature, the level of impact of each disruption on the farmers was captured on a five-point scale with 1. Much lower, 2. Lower, 3. Moderate, 4. Higher 5. Much higher (Chaudhuri *et al.*, 2018). Economic Vulnerability is considered the dependent variable in this study. In reviewing the literature, several indicators are identified to measure economic vulnerability. The relative distance to a minimum wage is used as the most appropriate indicator for this study to characterize the economic behavior of farming systems (result per farmer). In this study, the relative distance (RD) refers to the distance between the farmer's

average income and the minimum wage (MIN) (Sneessens *et al.*, 2019). This indicator permits the integration of a social dimension into the evaluation of vulnerability and effective economic performance which is a necessary first step to being able to cope with the risks. A minimum wage is considered the threshold for defining a farmer's ability to maintain a sufficient income. Throughout the survey, the farmer's "Monthly Average Income Level (Avg_Income) from Farming" was collected. This average income is compared with the minimum wage in Sri Lanka during the pandemic period to identify the level of economic vulnerability of farmers. In 2020 and 2021, the national minimum wage in Sri Lanka was 12,500 Sri Lankan rupees (NMW Sri Lanka, 2022). The relative distance (RD) is considered a key measurement to categorize the level of vulnerability into three categories such as 1. Low Vulnerability, 2. Moderate Vulnerability 3. High Vulnerability.

3.2 Population and sampling

The main population of this study included all small-scale vegetable and fruit farmers in every district in Sri Lanka. Higher production was recorded in eight districts of vegetable agriculture amongst the rest: Badulla, Nuwara Eliya, Puttalam, Anuradhapura, Hambantota, Rathnapura, Kurunegala, and Kandy (Export Development Board (EDB); Sri Lanka, 2022; Wijesinghe *et al.*, 2021). Almost half of the low-income rural cultivators are small-scale farmers. About 1.65 million small-scale farmers cultivate in less than 2 hectares on average and contribute to 80% of the total annual food production. Hence, small-scale farmers have been chosen for the present study as they are more vulnerable to this crisis than other types of farmers. However, a well-established national database is absent to identify vegetable and fruit cultivators in Sri Lanka (Wijesinghe *et al.*, 2021). The multi-stage random sampling technique was employed to select a representative sample for this study to achieve the research objective. In the first stage, eight districts were selected based on the highest production of vegetables and fruits in the 2018/2019 Maha season. In the second and third stages, the most appropriate divisional secretariat (DS) from each district and Agrarian Service Centers (ASC) in each division were selected respectively. These agricultural divisions and Agrarian Service Centers were identified according to a study conducted by Wijesinghe *et al.* (2021). Then, the villages of each selected ASCs with the highest production of vegetables and fruits were selected. Next, village-level farmers were randomly selected. Finally, thirty-five (35) small-scale farmers from each of the eight districts were selected to make the total of 280 (35*05 districts) respondents for this study.

3.3 Data collection

A survey is a process of collecting, analyzing, and interpreting data from a large group of people to discover new information about a group of people. A survey was conducted among the small-scale farmers to collect the primary data for this study. A questionnaire that consists of a series of closed-ended questions was used to obtain statistical data relating to the COVID-19-induced disruptions of the vegetable and fruit supply chain and its impact on the economic vulnerability of small-scale farmers (see Appendix). The first section of the questionnaire includes questions on the demographic data of vegetable and fruit farmers. The second section of the questionnaire consists of questions on four types of supply chain disruptions as explained under operationalization. The last section includes questions on economic vulnerability. Cronbach's alpha was estimated using the SPSS software to assess the internal consistency or reliability of the survey questionnaire of this study. In addition to that, the Kaiser-Meyer-Olkin measure of sampling adequacy (MSA) was used to imply the suitability of the data for factor analysis as a validation method. This survey questionnaire is translated into the native language of Sri Lanka so that farmers can properly understand the questions. A Google form was created to collect and save the survey data. Due to the limited

use of smart devices by Sri Lankan farmers, some responses were collected over the telephone. According to the designed sample size, 280 responses were collected for the study.

3.4 Data analysis

For quantitative data analysis, exploratory factor analysis and ordinal logistics regression were mainly applied as explained in the two sections below:

3.4.1 Exploratory factor analysis (EFA). The goal of exploratory factor analysis is to find the underlying variables or factors that explain the pattern of correlations within a set of observed variables. In data reduction, factor analysis is frequently used to identify a small number of factors that explain the majority of the variance observed in a much larger number of manifest variables (IBM Corporation, 2021). In this study, 16 items of measurement were identified under categories of four main supply chain disruptions, as represented in the operationalization table. Since the five-point Likert scale is used in this study, it is treated as an interval scale in running the exploratory factor analysis. An EFA was performed using principal component analysis and varimax rotation. The minimum factor loading criteria was set to 0.5. The commonality of the scale, which indicates the amount of variance in each dimension, was also assessed to ensure acceptable levels of explanation.

3.4.2 Ordinal logistics regression. According to the operationalization (Table 1), the impact of the COVID-19 pandemic on the vegetable and fruit supply chain was considered through Supply Disruption (SD), Production Disruption (PD), Transportation Disruption (TD), and Demand Disruption (DD). Disruptions in supply chains are assessed by multiplying the probability of their occurrence by their impact. In this study, the probability was considered constant considering the pandemic phenomenon. The level of impact of disruption was captured on a five-point scale with 1. Much lower, 2. Lower, 3. Moderate, 4. Higher 5. Much higher. So, they were considered ordinal variables. Economic Vulnerability was considered the dependent variable in this study. The relative distance (RD) was considered a key measurement to categorize the vulnerability level into three categories such as 1. Low Vulnerability, 2. Moderate Vulnerability and 3. High Vulnerability. Therefore, the dependent variable was also considered as an ordinal variable. Considering the data type, Ordinal logistic regression was used as the main quantitative data analysis technique of this study. Ordinal logistic regression is a method for predicting an ordinal dependent variable, given one or more independent factors (Luers, 2020). Four assumptions of ordinal regression were satisfied to get a valid result for this study (Restore, 2011). Assumption #1: The dependent variable should be measured at the ordinal level. In this study, the economic vulnerability (dependent) variable consists of ranking categories such as a 3-point scale explaining the degree to which a farmer is exposed to the vulnerability during the crisis period ranging from 1. Low Vulnerability, 2. Moderate Vulnerability 3. High Vulnerability. Assumption #2: One or more independent variables that are continuous, ordinal, or categorical variables. Four main factors in this study result from exploratory factor analysis, and they can be considered as ordinal variables which include Likert items (5-point scale from "Much lower" through to "Much Higher"). However, ordinal independent variables were treated as continuous variables in running an ordinal logistic regression in SPSS Statistics (Restore, 2011). Assumption #3: There is no multicollinearity which occurs when two or more independent variables are highly correlated with each other. To determine if multicollinearity is a problem, variance inflation factor (VIF) values were produced for each of the predictor variables using the SPSS software. Assumption #4: Having proportional odds means that each independent variable has an identical effect at each cumulative split of the ordinal dependent variable. It was tested in SPSS Statistics using a full likelihood ratio test comparing the fitted location model to a model with varying location parameters. Once the four assumptions were satisfied,

the ordinal logistics regression was run using the generalized linear model option in the SPSS software to get more powerful test results.

4. Results

4.1 Exploratory factor analysis

An important step involved weighing the overall significance of the correlation matrix through Bartlett's test of sphericity, which provides a measure of the statistical probability that indicates whether the correlation matrix has significant correlations among some of its components. The results were significant, x2 (n = 280) = 1709.662 ($p < 0.001$), which indicates its suitability for factor analysis (see Table 2).

The Kaiser-Meyer-Olkin measure of sampling adequacy (MSA), which indicates the appropriateness of the data for factor analysis, was 0.802. Therefore, data with MSA values above 0.800 are considered appropriate for factor analysis. The results of commonalities showed that all commonalities were over 0.5 except one variable called PD1 - Reduction/discontinuation of the Production which assured acceptable levels of explanation of each dimension (see below Table 3). PD1 was not removed as it does not have significant implications on the overall model.

Finally, the factor solution derived from this analysis yielded four factors for the scale, which accounted for 66.419% of the variation in the data (see Table 4).

Nonetheless, in this initial EFA, one item (SD4 There was a change in the quality of raw material supplied) significantly failed to load any dimension. Moreover, one item (SD5 A key supplier has gone out of business) loaded onto a factor other than its underlying factor. Hence,

Table 2. KMO and Bartlett's test

KMO and Bartlett's test		
Kaiser-meyer-olkin measure of sampling adequacy		0.802
Bartlett's test of sphericity	Approx. Chi-Square	1709.662
	Df	91
	Sig	0.000

Source(s): Authors' own work

Table 3. Communalities

Communalities	Initial	Extraction
SD1 - Supply Failures	1.000	0.795
SD2 - Extended Lead Time	1.000	0.763
SD3 - Price of Agri-Inputs	1.000	0.575
PD1 - Reduction/discontinuation of the Production	1.000	0.338
PD2 - Cultivation Cost	1.000	0.655
PD3 - Quantity of Crop Yields	1.000	0.709
PD4 - Quality of Crop Yields	1.000	0.668
PD5 - Unavailability of Labors	1.000	0.575
TD1 - Transportation interruptions in Agri-Inputs Supplies	1.000	0.559
TD2 - Transportation interruptions in Agri-Produce Deliveries	1.000	0.756
DD1 - Quantity Demanded by Customers	1.000	0.647
DD2 - Delays in Finished Goods Deliveries	1.000	0.736
DD3 - Amount of products disposed	1.000	0.745
DD4 - Prices of products sold	1.000	0.777

Source(s): Authors' own work

Table 4. Total variance

Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.529	32.353	32.353	4.529	32.353	32.353	4.061	29.006	29.006
2	2.468	17.632	49.985	2.468	17.632	49.985	1.930	13.785	42.790
3	1.195	8.533	58.518	1.195	8.533	58.518	1.661	11.866	54.657
4	1.106	7.901	66.419	1.106	7.901	66.419	1.647	11.763	66.419
5	0.952	6.797	73.217						
6	0.823	5.876	79.093						
7	0.628	4.488	83.581						
8	0.562	4.013	87.594						
9	0.434	3.100	90.694						
10	0.335	2.391	93.085						
11	0.297	2.122	95.207						
12	0.262	1.873	97.080						
13	0.212	1.512	98.592						
14	0.197	1.408	100.000						

Source(s): Authors' own work

two items were removed from further analysis. The EFA was repeated without including the aforesaid items and the four-dimensional structure was confirmed through the results of the new analysis (see Table 5). Factor 1 includes items such as SD1and SD2. Factor 2 includes items such as SD3, PD1, and PD2. Factor 3 includes items such as PD3, PD4, and PD5. Factor 04 includes items such as TD1, TD2, DD1, DD2, DD3, and DD4.

4.2 Ordinal logistics regression analysis

According to the four factors generated from exploratory factor analysis, four composite variables were created such as Factor 1 – Supply Failures (Mean (SD1, SD2)), Factor 2 – Cultivation Cost (Mean (SD3, PD1, PD2), Factor 3 – Cultivation Productivity (Mean (PD3, PD4, PD5)) and, Factor 4 -Transportation and Demand (Mean (TD1, TD2, DD1, DD2, DD3, DD4). VIF values were produced for each of these predictor variables to determine whether there is a multicollinearity issue or not. Thus, the generated results (Supply Failures −1.240, Cultivation Cost −1.160, Cultivation Productivity-1.248, Transportation and Demand −1.085), concluded that there is no severe multicollinearity issue as all the VIF values are closer to 1. Therefore, assumption three in running the ordinal logistics regression was satisfied. The omnibus test result is considered to assure the satisfaction of the 4th assumption. This result indicates that the full model was a significant improvement in fit over the null (no predictors) model [$x2\,(4) = 201.957, p < 0.001$]. A statistical test that measures how well sample data matches a distribution from a population with a normal distribution is referred to as goodness-of-fit (Restore, 2011). If the Deviance/df is below 2.5, it indicates an acceptable model fit. In this model, the deviance value/df is 0.69 which represents the acceptable model fit.

Running the generalized linear model, allowed us to obtain both Wald tests of the predictors (Parameter Estimates-See below Table 6) and Likelihood ratio tests. For the most part, the *p*-values from both tables were precisely consistent. The regression coefficients are interpreted as the predicted change in the log odds of being in a higher (as opposed to lower) group/category on the dependent variable (controlling for the remaining independent variables) per unit increase on the independent variable (Restore, 2011). This generally indicates that as the impact level increases on a disruption variable, there is an increased

Rotated component matrix

	Component			
	1	2	3	4
SD1 - Supply Failures				0.815
SD2 - Extended Lead Time				0.844
SD3 - Price of Agri-Inputs			0.711	
PD1 - Reduction/discontinuation of the Production			0.563	
PD2 - Cultivation Cost			0.707	
PD3 - Quantity of Crop Yields		0.737		
PD4 - Quality of Crop Yields		0.695		
PD5 - Unavailability of Labors		0.741		
TD1 - Transportation interruptions in Agri-Inputs Supplies	0.651			
TD2 - Transportation interruptions in Agri-Produce Deliveries	0.850			
DD1 - Quantity Demanded by Customers	0.797			
DD2 - Delays in Finished Goods Deliveries	0.840			
DD3 - Amount of products disposed	0.855			
DD4 - Prices of products sold	0.859			

Source(s): Authors' own work

Table 5.
Rotated component matrix

Table 6. Parameter estimates

Parameter estimates

Parameter		B	Std. Error	95% wald confidence interval Lower	95% wald confidence interval Upper	Hypothesis test Wald chi-square	Hypothesis test df	Hypothesis test Sig	Exp(B)	95% wald confidence interval for exp(B) Lower	95% wald confidence interval for exp(B) Upper
Threshold	[EV1VulnerabilityLevel = 1.0]	10.143	1.4225	7.355	12.931	50.838	1	0.000	25403.236	1563.298	412796.781
	[EV1VulnerabilityLevel = 2.0]	14.100	1.5873	10.989	17.211	78.906	1	0.000	1328998.572	59210.516	29829789.109
SupplyFailures		−0.140	0.1797	−0.493	0.212	0.611	1	0.435	0.869	0.611	1.236
CultivationCost		−0.203	0.2625	−0.717	0.312	0.597	1	0.440	0.816	0.488	1.366
CultivationProductivity		−0.096	0.2112	−0.510	0.318	0.206	1	0.650	0.909	0.601	1.374
TransportationandDemand		3.560	0.3436	2.887	4.234	107.368	1	0.000	35.169	17.935	68.964
(Scale)		1[a]									

Source(s): Authors' own work

probability of falling at higher levels of economic vulnerability. Out of the four factors considered, one factor – Transport and Demand is statistically significant, which is a *p*-value less than 0.05. When transportation and demand disruptions increase, there is a predicted increase in the log odds of a farmer being in a higher level of economic vulnerability.

The Exp(B) column contains odds ratios reflecting the multiplicative change in the odds of being in a higher category on the dependent variable for every one-unit increase on the independent variable, holding the remaining independent variable constant. An odds ratio> 1, suggests an increased probability of being at a higher level on the dependent variable as values on an independent variable increase, whereas a ratio <1, suggests a decreased probability with increasing values on an independent variable. An odds ratio = 1, suggests no predicted change in the likelihood of being in a higher category as values on an independent variable increase. Since the odd ratio of Transportation and Demand (Exp(B) = 35.169) is greater than 1, it suggests an increased probability of being in a higher level of Economic Vulnerability when values on this factor increase.

5. Discussion

5.1 COVID-19 induced disruptions and economic vulnerability

The exploratory factor analysis generated four main factors from the sixteen measurement items identified through the literature review which determined the COVID-19 Pandemic-Induced disruptions. According to the results of the ordinal logistic regression procedure, the factor of Transportation and Demand was identified as the statistically significant factor. The transportation and Demand factor consisted of 6 items such as TD1-Transportation interruptions in Agri-Inputs Supplies, TD2 - Transportation interruptions in Agri-Produce Deliveries, DD1 - Quantity Demanded by Customers, DD2 - Delays in Finished Goods Deliveries, DD3 - Amount of products disposed, DD4 - Prices of products sold. Since COVID-19 is a novel phenomenon that disrupted most of the global food supply chains, it is much needed to identify the most suitable factors in measuring the COVID-19-induced disruptions to contribute to the literature development. Through the above analysis, it is suggested that the agriculture supply chains were mainly disrupted due to these transportation and demand disruptions during the pandemic period and those disruptions can be identified as significant positive predictors of the economic vulnerability levels of the small-scale farmers in Sri Lanka.

Both foreign and local research studies have identified Transportation interruptions as a primary cause of increasing farmers' economic vulnerability during the crisis period (Aday and Aday, 2020; Deconinck *et al.*, 2020; Galappattige, 2020; Michele, 2020; Rathnayake *et al.*, 2022; Roshana and Hassan, 2020). Regarding the regression output, TD1-Transportation interruptions in Agri-Inputs Supplies, and TD2 - Transportation interruptions in Agri-Produce Deliveries could be identified as statistically significant factors. Galappattige (2020); Rathnayake *et al.* (2022); Roshana and Hassan (2020) have highlighted that farmers were unable to reach Agri-Input suppliers and send their Agri-products to markets on time owing to lack of transportation facilities and travel restrictions. As a result, delivery of vegetables and fruits to economic centers and other major marketplaces was delayed, and farmers frequently had to dispose them in bulk due to their short perishability. The closure of the Dambulla commercial hub had a negative impact because it resulted in large quantities of unsold produce being discarded (Roshana and Hassan, 2020). These logistical challenges and border clearance delays disrupt the entire food supply network and disproportionately impact perishable high-value items like vegetables and fruits (Michele, 2020). However, Agricultural operations continued even during the pandemic, despite severe logistical challenges (Aday and Aday, 2020; Deconinck *et al.*, 2020; Galappattige, 2020; Michele, 2020; Rathnayake *et al.*, 2022; Roshana and Hassan, 2020). This fact can be further proved through

the current study as the farmers claimed that they continued the cultivation activities during the pandemic period. Hence, the production disruption has not been detected as a statistically significant factor in the analysis.

Based on the above analysis, Low demand from the wholesalers, retailers, and end customers for vegetable and fruit items, Delays in Agri Produce deliveries, Increasing the amount of Agri-products disposed without selling, and Price changes in products sold, have been identified as the significant demand disruptions experienced by the farmers during the pandemic period. Moreover, both foreign and local studies identify that the food consumption patterns of customers have dramatically changed during the pandemic period; consequently, farmers and wholesalers encountered low demand from the end customers, making those sellers further economically vulnerable (Aday and Aday, 2020; Husain Arif *et al.*, 2020; Barman *et al.*, 2021; Godrich *et al.*, 2022). Galappattige (2020) stated that consumer movement restrictions have disrupted the usual trading practices, causing product prices to fluctuate high and low in pursuit of a supply-and-demand equilibrium. As mentioned by Roshana and Hassan (2020), due to the imposed curfew and lockdown, there was a shortage of high-value commodities such as fresh fruit and vegetables that were brought to market. Consequently, there was severe disruption to the supply of perishable fruits and vegetables. As a result of that, delivery of fresh food to customers was delayed, causing food waste and farmers losing income (Roshana and Hassan, 2020). Hence the findings of this quantitative study can be aligned with the findings of the qualitative studies conducted in the Sri Lankan context.

Many farmers suffered serious losses as a result of the control measures, and temporary import controls hindered the trade (Roshana and Hassan, 2020). In terms of average income gathered and its comparison with the minimum wage rate, the percentages of each vulnerability level have been Low - 30%, Mid - 51.1%, and High - 18.2% during the pandemic period (2020–2021), whereas the percentages before the pandemic period (2019) have been Low - 73%, Mid - 26.1%, and High - 07%, in the considered sample. Overall, it is concluded that the interruption caused by COVID-19 has exacerbated the economic vulnerability of small-scale vegetable and fruit farmers in Sri Lanka. Similarly, Rathnayake *et al.* (2022) discovered that the income of Sri Lankan vegetable farmers has been reduced considerably due to three primary factors: disruptions in input supply, disruptions in markets, and unemployment in the general population. Finally, it is concluded that the impact of the pandemic on Sri Lankan vegetable and fruit cultivators is multifaceted and exacerbates their vulnerability in the long run (Rathnayake *et al.*, 2022).

5.2 Practical implications of the study

The findings of this study are crucial for formulating novel policies to improve the sustainability of Sri Lanka's agricultural sector and to alleviate the poverty level of Agri-communities in the countryside. Since agriculture is a crucial component of the economy, the government should issue clear directives to banks and other financial institutions to offer credit facilities to promote the financial stability of farmers during crisis periods. In addition, the current study emphasizes the importance of establishing a government information center to identify the supply and demand level of the marketplace promptly as well as to determine the appropriate import and export levels of Agri products to avoid wastage. In addition, the respective government authorities should develop programs for importing and distributing adequate quantities of fertilizers among farmers at controlled prices so that they can continue their operations without any interruptions. Moreover, the government can collaboratively work with private organizations to streamline the Agri-Input supply process. Further, the government should critically consider the issues of farming families and the strategies which could promote their continuous involvement in agriculture. Due to the

difficulties faced by the farmers, they withdraw from farming and try to seek employment in other industries; consequently, this might create issues of food shortage in the foreseeable future and the government might have to import more Agri – products for daily consumption that in turn might cause a surge in the economic issues of the country.

Based on the findings of the current study and reviewing the literature, the following practical implications and recommendations can be suggested (see Table 7).

6. Conclusion

The COVID-19 pandemic erupted a variety of effects on the Sri Lankan vegetable and fruit food supply chain, which has predominantly collapsed due to a failure at the producer end of the supply chain. Since COVID-19 is a novel phenomenon that has significantly disrupted most of the global food supply chains, scholars must identify the most appropriate factors in measuring COVID-19-induced disruptions. Hence, this study contributed to the literature development by suggesting the appropriate factors which could be used to measure supply chain disruptions likely to be caused by pandemics. The four major supply chain disruption categories were considered to examine the COVID-19-induced disruptions experienced by vegetable and fruit producers in Sri Lanka. The primary data for this study were collected

No.	Practical implication	Recommendations for implementation
1	Providing more loans or allowances to farmers through state banks	- Providing clear instructions to state banks to offer loan facilities for farmers - Giving loan facilities with a longer repayment period - Arranging awareness sessions for farmers on loan facilities and allowances
2	Establishing a government information center	- Collecting, analyzing, and sharing real-time information on supply and demand levels of the marketplaces - Implementing IT systems/websites for information dissemination
3	Determine the appropriate import and export levels of Agri Produces to avoid the wastage	- Establishing a government information center - Collecting, analyzing, and sharing real-time information on supply and demand levels of the marketplaces
4	Promoting organic fertilizers among the farmers	- Arranging awareness programs on the applications of organic fertilizers - Providing adequate resources
5	Developing programs for importing and distributing adequate quantities of Agri-inputs at controlled prices	- Setting controlled prices for fertilizers and other Agri-Inputs - Developing collaborations with private suppliers to streamline the Agri-Inputs importing process - Developing effective delivery channels
6	Upgrading the Cold storage facilities near the economic centers	- Building new warehousing and cold storage facilities - Signing contracts with private warehousing service providers
7	Motivating farming families to remain active in agriculture	- Implementing an image-building campaign for Agriculture Sector - Organizing the awards ceremonies for appreciating the contribution of the farmers

Table 7.
Practical implications of the research

Source(s): Authors' own work

from the 280 farmers living in the eight highest crop-grown districts in Sri Lanka. Then, the exploratory factor analysis and ordinal logistics regression analysis were applied to analyze the survey data collected. Out of 16 measurement items considered, 14 items were selected for the regression analysis based on the results of the exploratory factor analysis. The results of the regression analysis revealed that the transportation disruptions and demand disruptions have considerably affected the economic vulnerability of small-scale farmers more than the supply and production-related disruptions. Transportation disruption was a primary cause for the increment of farmers' economic vulnerability during the crisis period as they were unable to reach Agri-Input suppliers and send their Agri-products to markets on time due to a lack of transportation facilities and travel restrictions. Low demand from the customers for vegetable and fruit items, Delays in Agri Produce deliveries, Disposal of the amount of Agri-products without selling and Price changes in products sold can be identified as significant demand disruptions experienced by the farmers during the pandemic period. The negative effects of COVID-19 have exacerbated the economic situation, implying that protecting the incomes of small-scale farmers during a pandemic could support the long-term viability of the vegetable and fruit sectors.

The results of this study highlight the need for the government and other relevant institutions to focus on the vegetable and fruit industry to increase the prosperity of farmers and the nation. To improve the effectiveness of the vegetables and fruit supply chains and to encourage all stakeholders, including farmers, to continue their agribusinesses, the government should provide the necessary infrastructure and facilities. Hence, the findings of this study are useful in understanding what happened, how organizations and individuals acted and how supply chain architecture and operations might be altered in the event of another pandemic. Hence, these empirical findings will be more practical in developing new policies and propelling agriculture to the next level of excellence. However, it is difficult to generalize these findings to the entire farming population as the current study is limited to the Sri Lankan context with a sample size of only 280 small-scale farmers. Moreover, the major obstacle can be termed as the absence of a central database to identify the farming population in conducting Agri research in the Sri Lankan context. The COVID-19 experience would be worthy of academic and management attention even though there would be an infrequent possibility of recurrence of the pandemics. Therefore, future research potentials exist in the domains of supply chain management and economics incorporating COVID-19 new phenomenon and crisis theories to construct new models and concepts.

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Appendix

COVID-19 Pandemic-induced Disruptions and Economic Vulnerability in Vegetable and Fruit Supply Chains in Sri Lanka: A Supply Side Perspective

This survey is conducted with the purpose of Investigating the impact of COVID-19 pandemic on the Vegetable and fruit farmers in Sri Lanka. If you are a vegetable and fruit farmer in Badulla, Nuwara Eliya, Anuradhapura and Hambantota districts, you are kindly invited to participate in this research study and your participation in this study is voluntary. The filling of this survey questionnaire will take approximately two minutes only. Your response will be confidential, and your personal details will not be disclosed. The result of this survey is used only for the academic purposes.

Demographic Data of Vegetable & Fruit Farmers/Respondents

D1 Age: 20-29 ☐ 30-39 ☐ 40-49 ☐ 50+ ☐

D2 Household Size/Family Members: 1 ☐ 2_3 ☐ 4_5 ☐ >5 ☐

D3 No. of earners: 1 ☐ 2 ☐ 3 ☐ >4 ☐

D4 Types of products grown : Vegetables ☐ Fruits ☐ Both ☐

D5 Farmer's years of experience in agriculture:

1-10 Years ☐ 11-20 Years ☐ 21-30 Years ☐ > 30 Years ☐

D6 Land area of fruit and vegetables grown:

Less than 1 Acres ☐ 1-2 Acres ☐ 2 Acres ☐ 2-5 Acres ☐

D7 District: Badulla ☐ Nuwara Eliya ☐ Anuradhapura ☐ Hambantota ☐

D8 Division: ……

D9 Agrarian Service Center: ……

Based on your experience during the pandemic period, select the most suitable option for the below question.

COVID-19 Induced Supply Disruptions

SD1 We experienced supply failures that affect the production during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

SD2 We experienced extended lead time at the supplier's end during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

SD3 There was a change in the price of raw materials during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

SD4 There was a change in the quality of raw material supplied during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

SD5 A key supplier has gone out of business during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

COVID- 19 Induced Production Disruptions

PD1 There was a reduction or temporarily discontinuation of the Production activities during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

PD2 There was a change in the cultivation cost during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

PD3 There was a change in the quantity of crop yields during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

PD4 There was a change in the quality of crop yields during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

PD5 There was unavailability of labor during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

COVID-19 Induced Transportation Disruptions

TD1 There were transportation interruptions in getting the Agri-Inputs from suppliers during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

TD2 There were transportation interruptions in providing the production outputs for traders/economic centers during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

COVID-19 Induced Demand Disruptions

DD1 There was a change in the quantity demanded by the customers during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

DD2 There were delays in finished goods (vegetables and fruits) deliveries during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

DD3 There was a change in the amount of products disposed during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

DD4 There was a change in the prices of products sold to the customers during the pandemic period.

1.Much lower ☐ 2. Lower ☐ 3. Moderate ☐ 4. Higher ☐ 5. Much Higher ☐

Economic Vulnerability

EV1 Mention the Average Monthly Income Level (LKR) earned from Farming during the pandemic Period (2020 – 2021Years) ……

EV2 Average difference between the Income earned during the pandemic period and before the pandemic period. ……..

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