Risk and Vulnerability Assessment for Resilience Building in the Colombo City Region Food System (CRFS)

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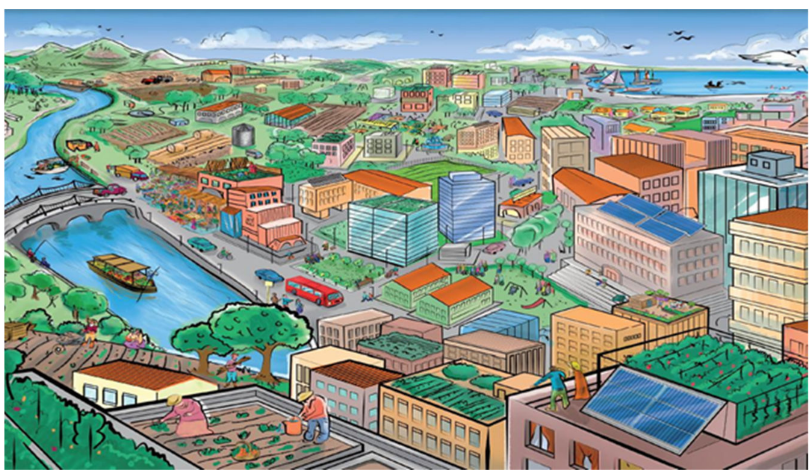

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EXECUTIVE SUMMARY

The twin challenges of climate change and the Covid-19 pandemic are food system drivers capable of influencing the food system outcomes comprising food security, social welfare and environmental capital. The impact of climate change in the context of a severely weakened economy due to Covid-19 has exacerbated the risks of food availability and accessibility across the country especially, to the poor and vulnerable communities in the city region.

This assessment examines the impact of climate change and Covid-19 on the Colombo City Region Food System (CRFS) to identify existing food system vulnerabilities and provide information to cope with these shocks and uncertainties to build a resilient food system. The CRFS assessment considers rural-urban linkages including foodsheds that feed Colombo. The five food supply chains; paddy/rice (Ampara, Anuradhapura, Polonnaruwa); coconut (Kurunegala, Puttalam, Gampaha); upcountry vegetables (Nuwaraeliya, Badulla) low country vegetables (Anuradhapura); and the Southern and Western fishing belts representing the Colombo CRFS were assessed.

In this research, the risk assessment framework specified in the IPCC Fifth Assessment Report (AR5) was used as a guide. A mixed approach was used to collect data consisting of an extensive web-based search of climate change impact-related media coverage over six years (2015-2020), secondary data, literature and document review, stakeholder interviews and expert consultation. The individual events identified were used to determine the nature of the hazard, exposure and vulnerability. The data were analyzed to derive risk/vulnerability indices and degrees of risk/vulnerability at individual supply chain nodes.

The major climate hazard that has impacted the three selected rice-producing districts viz., Ampara, Anuradhapura and Polonnaruwa is drought. There is a clear relationship between the intensity of the climate hazard and paddy production in these districts. Among the three districts, Anuradhapura is more vulnerable and carries higher risk. The paddy production drop in 2017 attributed to drought created a shortfall in rice for local consumption prompting the importation of significant volumes of rice. This is a clear indication of the impending threat of climate change to food self-sufficiency in Sri Lanka. Paddy storage, milling and wholesale operations are mainly in the hands of the private sector. The government agency mandated to oversee the paddy and rice supply chain operations plays a sedentary role. Climate change has threatened the operations of small- and medium-scale rice mills as a short supply of paddy makes these mills redundant. Climate change can be considered as one of the main contributors to rice price volatility. There are a noteworthy number of reports of confiscating significant amounts of spoiled rice stocks in the media. This also could contribute to price fluctuation. This warrants further investigation as significant levels of spoilage will have implications for rice prices and food security. Frequent price fluctuations can impact rice consumption and thus food energy intake and protein intake of the poorer segments in the Colombo city region. There is serious institutional fragmentation and a disconnect among public and private sector stakeholders in the rice sector. Therefore, it is necessary to develop a coordination mechanism involving relevant stakeholders from the public and private sectors.

Most up-country vegetable types are supplied to the Colombo city region from Nuwaraeliya and Badulla districts while low country vegetables come from various other parts of the

country. The major climate hazards affecting Nuwaraeliya and Badulla districts are wind, landslides, flood and heavy rains while the major low country vegetable-producing district, Anuradhapura is affected by droughts. Upstream vegetable supply chains in Nuwaraeliya and Badulla districts are highly vulnerable due to wind events seriously affecting vegetable production. Anuradhapura District is moderately vulnerable due to the availability of alternative sources of water for the cultivation of low country vegetables. The findings of the assessment point to the conclusion that the impact of climate hazards on production and excessive postharvest losses along the supply chain are the main reasons for the unaffordability of vegetables to the poorer segments in the Colombo city region.

The Dedicated Economic Centre (DEC)-based traditional vegetable supply chains are responsible for about 85% of vegetable supplies to the Colombo city region. Supermarket chains hold about a 10% market share in the vegetable supplies to Colombo city region. The traditional supply chains centred around DECs have largely contributed to the Colombo CRFS. However, DECs lack basic infrastructures such as cold chain facilities, storage space, other basic amenities and technical and management know-how for smooth operation of these centres. These centres need to be equipped with databases connected to real-time decision support systems to determine the demand and supply of vegetables to the Colombo city region. Therefore, investments in infrastructure and capacity development are essential. Vertical integration of farmers to mainstream supply chains through networks of collection centres and investment in supply chain infrastructure is significant in pursuing supply chain collaboration and resilience. There are food safety and quality issues which at the farm level need to be enhanced by the adoption of modern technologies and practices such as GAP (Good Agricultural Practices). Further, studies are needed to understand the relationship between indiscriminate agrochemical usage and climate extremes, especially in the upcountry districts.

The wind is the common hazard affecting coconut production in the coconut triangle. There is a clear relationship between annual coconut production and Colombo retail prices. There was clear evidence to establish that when the coconut price escalates, the poorer segments are unable to afford coconut consumption with implications for household nutrition. The high volatility of coconut production and its link to coconut oil production and prices prompt consumers to shift from coconut oil to palm oil as well as to consume adulterated cooking oils leading to cancer and cardiovascular diseases. Therefore, the implementation of food safety regulations related to cooking oils is necessary to ensure food safety.

The major climate hazards that impact marine fishing are wind, cyclones and heavy rains. The fish prices are highly responsive to climate hazards. In the fish supply chain, the upstream nodes including production nodes are highly vulnerable to climate hazards due to lack of capacity resulting from poor socio-economic status and access to fishing gear and infrastructure. Extreme weather conditions can contribute to postharvest losses of fish as high as 40%. Adverse weather conditions in the production regions could push down the fish supplies to the Peliyagoda fish market and as a result prices are known to fluctuate. The available per capita fish supplies are not sufficient to meet the current fish requirements. The assessment points to the conclusion that fish is beyond the reach of the average household in the Colombo city region thus, climate hazards in the fishing regions can have a direct impact on protein malnutrition in the Colombo city region. Reducing the considerable postharvest losses along the fish supply chain itself can address the affordability issue to a larger extent.

Improvements to supply chain infrastructure such as cold storage, cold chain transport and modern processing facilities need to be addressed. There is also a lack of safety and food quality consciousness among domestic fish supply chain actors resulting in poor quality and food safety-compromised fish reaching the consumer with possible health implications. In light of climate change impacts, food safety and quality issues in the food system are aggravated and need further investigation and appropriate interventions.

The Covid-19 pandemic has exacerbated the existing vulnerability of the Colombo city region (a high proportion of the population is dependent on daily wages earned from the informal sector). The vulnerability of most of the food supply chains became apparent during the unfolding of the pandemic. The two food distribution hubs, the Peliyagoda fish market and the Manning market were seriously affected with complete disruption to the main food supply and distribution channels feeding to the city region. There were some notable initiatives to cope with the pandemic such as government-initiated relief measures to support vulnerable groups, encouragement for home gardening and local food production, the emergence of alternate food supply chains and food sharing in the community.

Since the bulk of food supplies to Colombo comes from many parts of the country, the governance of Colombo CRFS needs to be viewed from a national perspective. There are many policies, strategies and action plans in place to tackle the climate change challenge. However, actions are slow due to the complexities of multi-level governance. Early warning systems are plagued with inefficiencies in the government response, resource allocation and coherence and integration of the system leading to poor trust among stakeholders. Poor uptake and lack of innovative insurance products are the major constraints in the climate risk management field.

The assessment points to a clear link between climate hazards and crop and marine fish production implying the need to intensify climate change adaptation efforts. The poor availability of data related to the Colombo CRFS on food supplies and distribution is a serious limitation in identifying vulnerabilities in the food system and making recommendations to build a resilient food system. The authorities responsible should maintain and make available relevant information for decision-making.

The complex multilevel governance structure in place to address climate change and other shocks creates many challenges to coordinate and integrate a diverse set of institutions entrusted with the responsibilities at different scales viz., national, provincial, district and local. The best approach to capitalize on multilevel governance is to have an effective coordination mechanism, participatory decision-making, capacity development and allocate sufficient resources. Efforts to develop a stronger governance mechanism for building climate resilience in the Colombo city region will act as a catalyst for the rest of the country. Lessons and experience from the Colombo CRFS will also be useful to strengthen national efforts.

The food insecure population in the Colombo city region is significantly high and likely to increase further with the impending threat of climate hazards. The commodities assessed clearly show that the average household is unable to meet the minimum dietary requirements of these commodities due to price escalation. One of the main reasons for this is that climate hazards in production regions readily translate into price escalation in the Colombo city region. Therefore, Colombo CRFS reliance-building efforts should take this into cognizance in formulating strategies.

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Acronyms and abbreviations

AAIB	Agriculture & Agrarian Insurance Board
APSIM	Agriculture Production Systems Simulator
ANCP	Annual National Coconut Production
AR5	Fifth Assessment Report
CBSL	Central Bank of Sri Lanka
CBO	Community Based Organization
CCS	Climate Change Secretariat
CDA	Coconut Development Authority
CFC	Ceylon Fisheries Cooperation
CO_2	Carbon Dioxide
COVID-19	Coronavirus Disease of 2019
CRFS	City Region Food Systems
DCS	Department of Census and Statistics
DEC	Dedicated Economic Centre
DSD	Divisional Secretariat Division
EDB	Export Development Board
EEZ	Exclusive Economic Zone
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
FRP	Fibreglass Reinforced Plastic
GDP	Gross Domestic Product
GN	Grama Niladari
HIES	Household Income and Expenditure Survey
IPCC	Intergovernmental Panel on Climate Change
kg	Kilogram
LKR	Sri Lankan rupees
MDER	Minimum Dietary Energy Requirement
MFARD	Ministry of Fisheries and Aquatic Resources Development
MoA	Ministry of Agriculture
MoI	Ministry of Irrigation
MoHNIM	Ministry of Health, Nutrition and Indigenous Medicine
MPCS	Multipurpose Cooperative Societies
MPIEA	Ministry of Plantation Industries and Export Agriculture
MRI	Medical Research Institute
MRP	Maximum Retail Price
NAP	National Adaptation Plan
NARA	National Aquatic Resources Research & Development Agency
NCCAS	National Climate Change Adaptation Strategy
NCCP	National Climate Change Policy
NEAP	National Environmental Action Plan
NFB	Northern Fishing Belt
NGO	Non-Governmental Organization
PMB	Paddy Marketing Board
RBD	Refined, Bleached and Deodorized
SFB	Southern Fishing Belt
SROCC	Special Report on the Ocean and Cryosphere in a Changing Climate
UNFCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WFB	Western Fishing Belt
WHO	World Health Organization

CHAPTER 1 INTRODUCTION

Climate change and Covid-19 can be viewed as twin contemporary challenges to food systems, food security and many livelihoods dependent on agricultural production. Climate change is already having profound impact on food systems and their outcomes especially food security. Food systems can be viewed as dynamic interactions between and within the biogeophysical and human environments which lead to a set of activities ranging from production to consumption of food (Gregory et al., 2005). The food system is conceived as having both determinants and outcomes. The determinants belong to the biogeophysical, social, economic and political environments that influence how food system activities are carried out (known as food system drivers). The challenges of climate change are food system drivers capable of influencing the food system outcomes comprising food security, social welfare and environmental capital (Ericksen, 2008). The impact of climate change in the context of a severely weakened economy due to Covid-19 is likely to exacerbate the risks of food availability and accessibility especially to poor and vulnerable communities.

Colombo city region is heavily dependent on food supplies from the rural regions. Therefore, when rural agricultural regions are affected by climate and Covid-19 shocks, food supplies to the city region become disrupted making the city region highly vulnerable to the shocks, especially the poor and vulnerable segments of the city region dwellers. Climate shocks not only affect food production, but also affect the entire food supply chain including processing, distribution, wholesale and retailing, and consumption. Food affordability becomes the paramount challenge for the vulnerable as increased production volatility due to climate shocks is reflected through increased retail prices of food products.

The main focus of the assessment is to explore the impact of climate change and Covid-19 on Colombo City Region Food Systems (CRFS). A sustainable, resilient CRFS is expected to increase access to food; generate decent jobs and income; increase the region's resilience to shocks and minimize the dependence on distant supply sources; foster rural-urban linkages; promote ecosystem and natural resources management; and support participatory governance (Dubbeling et al., 2016).

A CRFS is defined by the Food and Agriculture Organization of the United Nations (FAO) as "*all the actors, processes and relationships that are involved in food production, processing, distribution and consumption in a given city region that includes a more or less concentrated urban centre and its surrounding peri-urban and rural hinterland*".

In this context, the assessment aims to identify current vulnerabilities of the food system to gain insights into factors that make the system vulnerable and to identify feasible adaptation interventions and priority actions to build food system resilience to these twin challenges.

The structure of the report is as follows: Chapter 1 covers the background and objectives of the assessment. Chapter 2 comprises a literature review. Chapter 3 covers the methods used for the study. Chapter 4 presents the impacts of climate change on paddy, vegetable, coconut and fish supply chains respectively. Chapter 4 also covers Covid-19 impact on CRFS and food system governance. Chapter 5 provides conclusions and recommendations to enhance the resilience of Colombo CRFS in light of the twin challenges of climate change and Covid-19.

CHAPTER 2 LITERATURE REVIEW

2.1 BACKGROUND

There is serious concern about the impact of climate change on food production, food security and livelihoods in Sri Lanka. The fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) projects that in the South Asian region the temperature is likely to rise by more than 2°C by the mid-21st century while more erratic rainfall and hot days along with an increase in extreme rainfall events are predicted (Hijioka et al., 2014). Historical climate data for Sri Lanka point to stronger warming extremes compared to other South Asian regions (Sheikh et al., 2015). Consistent with these findings, in Sri Lanka, studies indicate a warming trend in temperature along with more frequent droughts (Premalal & Punyawardena, 2013; Naveendrakumar et al., 2018). Both maximum and minimum temperatures in many districts of the country are rising; at the same time the number of rainy days is showing a downward trend, prolonging dry spells (De Costa, 2008; Marambe et al., 2013; Premalal & Punyawardena, 2013).

The country's agriculture sector continues to play a significant role in its economy accounting for 7% of the GDP (CBSL, 2019). About 41% of the economically active population engages in primary agriculture production (FAOSTAT, 2015). About 85% of the country's food requirement is produced by smallholder farmers cultivating on an average extent of 0.87 ha of which 66% is rainfed (Esham et al., 2006; Biradar et al., 2009; DCS, 2015). Therefore, climate stresses will impose serious strains on local food systems thereby affecting food system activities from production to consumption in several ways.

This section reviews the implications of climate change on the five selected supply chains namely, rice, coconut, vegetables (upcountry and low country) and fish. Most of the literature relevant to supply chains at the national level has direct relevance to the Colombo CRFS as more than 98% of all supplies of rice, upcountry and low country vegetables, coconut and fish are supplied from various production regions in the country. The review is limited to key supply chain components: production, storage and processing, wholesale and retail, and consumption. The literature review is organized under each product category covering the above nodes of the supply chain depending on the availability of published literature.

2.2 CLIMATE CHANGE IMPACT ON THE RICE SUPPLY CHAIN IN SRI LANKA

Rice is the staple food of Sri Lankans and it is a cultural heritage as rural communities have a close affinity with rice production. Rice is the second highest contributor to the agricultural GDP of the country with a contribution of 10% (CBSL, 2019). Annually about 1.2 million ha are cultivated in two cultivation seasons. Rice plays an important role in ensuring food security as it contributes 40% and 30% of total calorie and protein requirements respectively of an average Sri Lankan (Jayatissa et al., 2014). More than 1.8 million farmers and 30% of the labour force of the country is dependent on the paddy sector (Weerahewa et al., 2010). In the 2016/2017 Maha and Yala seasons, 500,606 and 316,278 households in the country were involved in paddy cultivation.

Rice production is plagued with a number of issues such as high cost of production, poor marketing and adverse climatic conditions. Climate change in terms of high temperature, rainfall variability and climate extremes is taking a heavy toll on rice production. Table 1 shows that rice production in the country is highly variable which can be attributed to climate variability (Esham et al., 2018). Climate change is projected to negatively impact rice productivity in the years to come (Cline, 2007; Nissanka et al., 2013; Ahmed & Suphachalasai 2014; Dharmarathna et al., 2014; Zubair et al., 2015).

Table 1. Paddy extent and production in Sri Lanka

Year	Extent (ha)	Production (million tonnes)
2010	1,065,281	4,300
2011	1,223,054	3,894
2012	1,066,616	3,846
2013	1,227,248	4,620
2014	964,264	3,381
2015	1,253,288	4,819
2016	1,141,323	4,420
2017	791,679	2,383
2018	1,040,954	3,930
2019	1,116,933	4,592

Source: Department of Census and Statistics (2019).

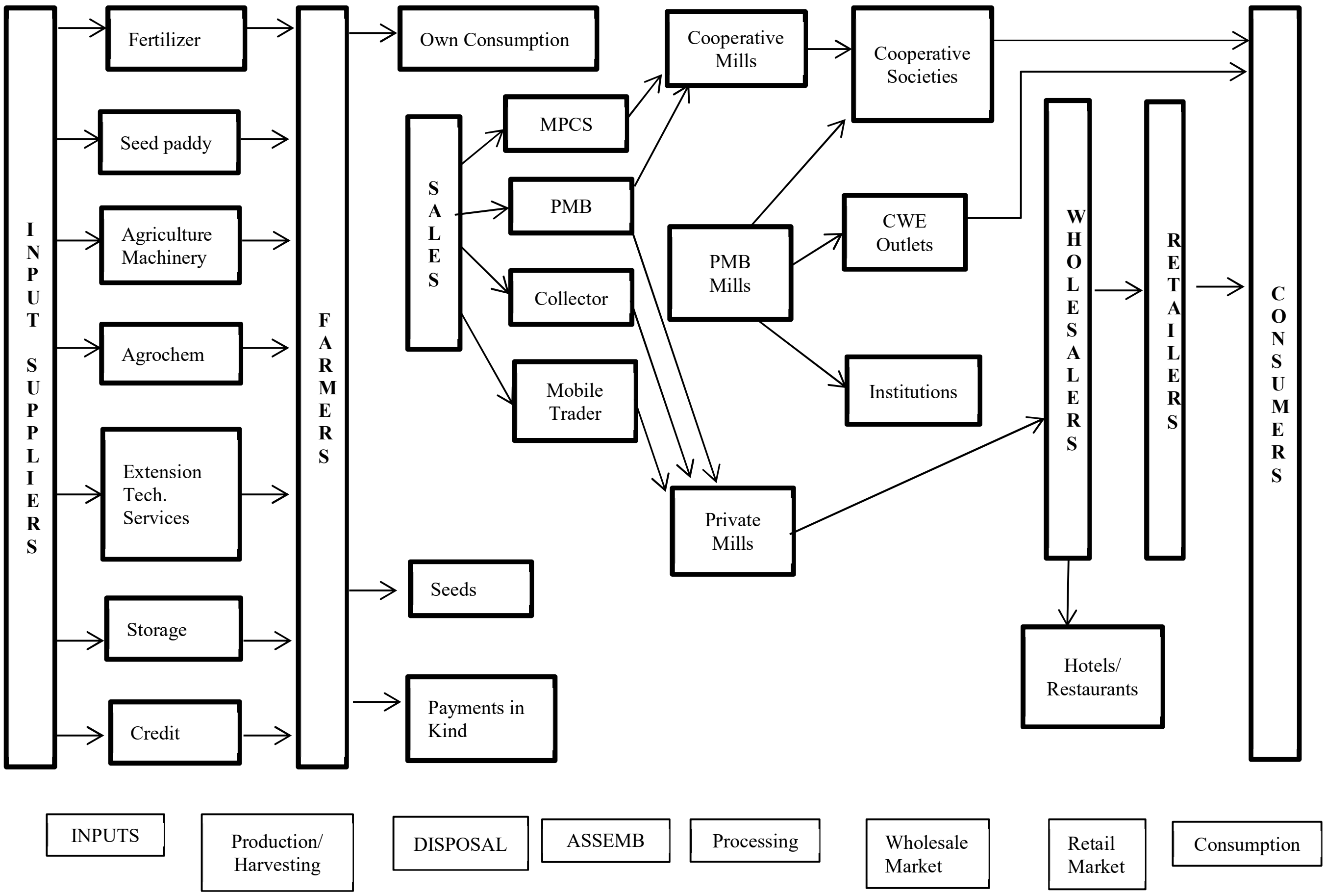


Figure 1. Paddy /rice value chain in Sri Lanka

Source: Senanayake et al. (2016).

Farmers have various channels to market their paddy. They include village collectors, the Paddy Marketing Board (PMB), Multipurpose Cooperative Societies (MPCS), private millers and mobile traders. The PMB is one of the marketing channels used by farmers (Wijesooriya et al., 2020). A significant number of farmers use paddy collectors to process the produce (Senanayake et al., 2016). The mill owners are another intermediary link in the supply chain, they purchase paddy from farmers and collectors. Wholesalers visit rice mills, purchase rice and transport it to wholesale and retail markets (Figure 1).

2.2.1 Rice production

In Sri Lanka, rice production is mainly impacted by rainfall and temperature. There is an acceptable correlation between the paddy yield and the climatic factors in several paddy producing districts including major producing districts such as Ampara and Kurunegala indicating that the paddy production is impacted by climate change (Amaratunga et al., 2020). Four districts viz., Ampara, Polonnaruwa, Anuradapura and Kurunegala contribute more than

50% to national paddy production. Presently, rice is being cultivated closer to their temperature tolerance threshold, any further increase in temperature is likely to severely compromise yield. Under future climate scenarios, the mean annual maximum and minimum temperatures are projected to rise significantly in South Asia (Mishra et al., 2020). Analysis based on monthly mean temperature data from 1869 to 2007 reveals that mean monthly maximum and minimum temperatures for Sri Lanka have increased by 2.6°C per 100 years and 1.7°C per 100 years, respectively (De Costa, 2010). A study that used climate data from 1961 to 2015 also reports a significant increase in annual maximum and minimum temperature, especially in the months of June and July (Naveendrakumar et al., 2019). In rice cultivation, maximum temperature becomes an important parameter during the flowering stage of the crop. Yield loss can happen due to exposure to high temperature which can significantly reduce pollen viability. When the crop is exposed to a temperature above 35^{0}C, spikelet sterility is greatly increased (Osada et al., 1973).

Rice cultivation is also highly sensitive to night time minimum temperature; increase in temperature is likely to severely affect rice yield as the yield is likely to decline by 10% for each 1°C increase in night time minimum temperature (Peng et al., 2004; Sivakumar & Stefanski, 2010). Another modeling study using panel data reveals that increasing temperatures beyond 2°C will seriously affect rice production compared to variation in rainfall. Simulations indicated that a temperature increase by 4°C either individually or together with varying rainfall would result in approximately 30% loss in production (Ratnasiri et al., 2019).

Cropping calendars and crop productivity are impacted by delayed onset of monsoon rains which have become a common occurrence in recent years (Chithranayana & Punyawardena, 2014; Senalankadhikara & Manawadu, 2010; Zubair, 2002). Rainfall variability was found to be a key determinant of paddy productivity, cropping intensity and crop failure in minor irrigation-based cultivation in Kurunegala District ranked as the fourth largest paddy producing district (Chandrasiri et al., 2020). The literature review shows that the Yala rains in the dry zone are highly variable and the onset time of both the Yala and Maha seasons are inconsistent (Chithranayana & Punyawardena, 2014). The irregular rainfall pattern has contributed to regional variations in paddy production, the highest level of variation is observed in the dry zone district of Anuradhapura (Fernando et al., 2010). Low rainfall often affects paddy production in the country. In 2016, rainfall was far below average; as a result, cultivation in the Maha season was only 540,000 ha compared to the previous year cultivation extent of 756,000 ha (FAO, 2017). A study on ENSO-induced rainfall variability revealed that in the El Niño phase, rice production in the Maha season often increased while in the Yala season production often decreased. In the La Niña phase, production in the Maha season decreased while production in the Yala season increased (Zubair, 2002). Extreme weather events increased from 2007 to 2016 with the exception of three years; extreme weather conditions have adversely impacted paddy production compelling importation of rice (Esham et al., 2018). Using the Agriculture Production Systems Simulator (APSIM) it is predicted that rice yields of the variety Bg 300 are likely to decrease in the Maha season by 18% and 31% in the wet zone and the rice yield of variety Bg 359 is likely to decrease in the Yala season by 17%, and 42% in the dry zone by the years 2050 and 2100, respectively (Amarasingha et al., 2018). Crop simulation models used for A1B1 scenario for the dry zone and intermediate zone project rice yields to drop by 29-34% and 20-32% respectively by the end of 2080 (Ahmed &

Suphachalasai, 2014). Another simulation study for the northwestern province reveals that rice yield is projected to decline by 12-22% and 28-42% in comparison with the simulated yield for the period 2012/2013 in the Maha and Yala seasons respectively (Nissanka et al., 2013). Projections for 2050 show that most rice growing areas will become water stressed due to less rainfall during the major season (De Silva et al., 2007). Under the changing climate, if Sri Lanka is to fulfill rising demand for rice by 2050, intensification of production with substantial increase in resource use like water and nitrogen fertilizer by as much as 69% and 23% respectively is necessary (Davis, Gephart & Gunda, 2015).

2.2.2 Paddy storage and processing, distribution, wholesale and retailing

The supplies to Colombo CRFS are affected by climate change impact on storage and processing of rice in the upstream stages of the rice supply chain with implications for city region consumers in terms of price and quality of rice available in the market. Rainfall variability and extreme rainfall seriously impact the pre- and postharvest handling stages of harvesting. Operations such as grain threshing require dry days. Rain during these crucial periods influences the grain quality in terms of attaining optimum moisture content (Esham et al., 2018). There is significant impact of temperature on paddy storage as dry matter loss of raw paddy nearly doubles when storage temperature increases from 26°C to 38°C (Awanthi et al., 2018). Poor storage and lack of storage technology results in losses estimated at about 5-6% (Palipane, 2000; Adhikarinayake et al., 2006). A survey conducted in 1988 in Anuradhapura District revealed that 4-6% of the paddy is lost during storage (Fernando et al., 1988). Deterioration of grain quality during storage leads to loss of seed viability and processing quality as well as enhanced fungal growth and mycotoxin production (Chakraborty & Newton, 2011). The milling quality of stored paddy is reported to degrade at high temperatures yielding large amounts of broken rice and low head rice (Awanthi et al., 2017).

2.2.3 Rice consumption

In Sri Lanka, household income and food prices are still key determinants that affect food consumption decisions of households. It is beyond doubt that there is a significant negative impact of climate change on food prices due to climate change-induced agricultural productivity changes (Akram & Hamid, 2014; Bandara & Cai, 2014).

Food price fluctuations negatively impact food consumption patterns of households (Pallegedara, 2019). For households in the western province, food prices act as a determinant of calorie availability (Nirmali & Edirisinghe, 2010). Due to the presence of more poor population in the urban sector as against other sectors, the urban sector is more vulnerable to food price increases (Ratnasiriet al., 2012). Hikes in food prices in Sri Lanka badly impact certain categories of the urban population, such as wage labourers (Hijiokaet al., 2014). Evidence indicates that high prices during the food crisis in 2008 led the urban poor to reduce food intake resulting in limited macro- and micro-nutritional intake (De Silva, 2010).

There is a co-integration between global food prices and local food prices in Sri Lanka (Selliah et al., 2015) even for domestically produced rice which became evident during the food crisis in 2007/2008. During that period rice prices doubled within one year. This has implications for calorie intake because households in Sri Lanka are reluctant to substitute rice despite rising prices (Sahn, 1988). It is projected that the climate change impact on production will increase the global market price of rice and wheat over the period up to 2040 (Cai et al., 2015). The retail price asymmetry that is common in the rice market leaves the urban poor in a precarious situation as they do not gain from price drops in the wholesale markets (Korale Gedara et al., 2015). These dynamics can impact the urban poor in terms of affordability of their staple food. Per capital rice availability in Sri Lanka over the last five decades has fluctuated around 90-120 kg per year while per capita consumption has been around 100-114 kg per year in the last few decades. A seven-day dietary estimate revealed that an average Sri Lankan consumes about 114.7 kg of rice and rice-based foods annually (Jayatissa et al., 2014). This indicates that during certain periods there can be a shortfall in rice supply and consequent price fluctuations in the rice market with implications for the poorer segment in society. Households in Colombo have shown a tendency of shifting from a cereal-based diet to more vegetable, meat and fish-based diets (FAO, 2016). A study on food consumption patterns suggests a complementary effect between rice with vegetables supporting the shift in food consumption patterns (Pallegedara, 2019). However, in Colombo District, 59% belongs to the food-insecure category (Deyshappriya, 2019). As such a shift in consumption patterns is not applicable to poorer segments. Evidence indicates that poor access to food due to low household income as one of the main reasons for high levels of child malnutrition manifested as stunting and underweight symptoms among children in Sri Lanka (Rannan-Eliya et al., 2013).

2.2.4 Climate change adaptation in the rice paddy supply chain

Literature related to climate change adaptation practices in the rice paddy supply chain is limited to the production node. Significant amount studies have covered different agroecological zones in which paddy is cultivated under different farming systems. Table 2 summarizes main adaptation practices followed by dry zone farmers.

Table 2. Climate change adaptation practices followed by dry zone paddy farmers

Adaptation practices	**Location, sample size and farming system**	**References**
*Bethma** practice, alternate wetting and drying (AWD) irrigation, alternative crop selection, and use of drought-resistant seeds	A sample of 192 paddy farmers from five villages in the dry zone of Sri Lanka. Minor and major irrigation	Truelove, Carrico and Thabrew (2015)
Bethma practice, when rains delay planting, farmers switch from long maturing (4-5 months) to short maturing (3 months) varieties, and invest in village tanks and agro wells	Anuradhapura District, rainfed village tank irrigation	Senaratne & Scarborough (2011)
Crop insurance, use of supplementary reservoirs for water storage, shift to shorter cycle crops, varieties, planting improved rice varieties	Anuradhapura District, 100 households	Herath & Thirumarpan (2017)
Planting other field crops, dry seeding, *bethma*/sharing land	Nine dry zone districts, 1,148 farming households in 30	Gnanasubramaniam & Hemachandra (2020)

	Grama Niladhari Divisions, major and minor irrigation schemes	
Engaged in off-farm labour, plant non-traditional crops in their paddy fields, employ water conservation strategies for rice farming	Dry zone districts, sample size 607	Williams & Carrico (2017).

* A water-sharing arrangement where the community collectively decides how much paddy land to cultivate.

2.3 IMPACTS OF CLIMATE CHANGE ON THE COCONUT SUPPLY CHAIN

2.3.1 Coconut production

Coconut is an essential ingredient in traditional Sri Lankan cuisine. It is said that coconut has been one of the three pillars of the economic heritage of the country and yet it has a significant contribution to foreign exchange earnings. Sri Lanka produces an average of 2,500 to 3,000 million nuts per year. The production comes from a total land extent of 1,095,982 acres (EDB, 2019). Kurunegala, Puttalam and Gampaha districts cover about 50% of total cultivated lands under coconut (CDA, 2016). According to the Ministry of Plantation Industries and Export Agriculture (MPIEA, 2020), in 2018, the total export earnings were LKR 94.7 billion (about 5% of merchandise exports). However, MPIEA (2020) reported reduction in coconut production while there was a hike of domestic consumption by 94 million nuts by 2018. Climate change exerts huge pressure on the coconut industry in balancing domestic consumption and export earnings when production drops.

In general, temperature, CO_2 and precipitation are the key factors that are influenced by climate change. Coconut cultivation in Sri Lanka mainly employs the rainfed irrigation system (Eriyagama et al., 2010). According to Peiris et al. (1995) rainfall and the temperature are the most important climatic factors that affect coconut production. According to Fernando et al. (2007) variability of the climate influences national coconut production in many different aspects. Along with their comparison between 1971 and 2001, income loss was significant due to climate variability that affected the production of coconuts.

Coconut production requires a continuous supply of fertilizers, crop management (irrigation) and planting materials and labour (Pathiraja et al., 2017). Jayawardhana & Warnakulasooriya (2020) reported reasons for coconut shortage such as poor agricultural practices, lack of government support and the negative effects of urbanization. Among these constraints climate change strongly influences crop management and moisture retention with implications for coconut yield. All these constraints contributed to the drop in average yield between 2015 and 2018.

The increasing trend in maximum temperature has affected the yield of coconut ultimately declining the production by 10% in the wet zone. Moreover, high temperature during the first four months in the reproductive stage (after inflorescence opening) has negative effects on productivity in the dry zone under rainfed conditions (Pathiraja et al., 2017). It was projected that the industry would lose LKR 4,795 million annually by 2020 assuming no adaptation measures are taken. Jayalath et al. (2020) also confirmed the negative effects of extreme weather events on coconut production.

Pathmeswaran et al. (2018) assessed the impacts of extreme weather events on coconut productivity from 1995 to 2015. They reported the effect of the number of intense rainfall events and average maximum temperature on productivity and concluded that the impact of extreme weather events on coconut productivity varied across different climatic zones represented by Gampaha, Kurunegala and Puttlam districts. Further, impacts of climate change on coconut have made the sector vulnerable, especially in monocropping farming systems (Jayalath, 2018).

2.3.2 Coconut storage, processing distribution, wholesale and retailing

When it comes to processing, kernel-based products and non-kernel products are the two major categories in Sri Lanka (Athukorala et al., 2017). The coconut value chain nodes include products ranging from raw coconut, oil and coconut milk based on the kernel and other byproducts from coconut waste, such as coconut fibres and shells. Hence, stakeholders through the supply chain can be categorized into two main categories: (1) those who deal with food-based products such as desiccated coconut millers, copra manufacturers, coconut oil manufacturers and (2) those who deal with non-food-based products such as shell charcoal manufacturers, fibre millers, value-added fibre product manufacturers and activated carbon manufacturers (EDB, 2019). However, growers and exporters are common stakeholders in those two main categories. Pathiraja et al. (2017) indicated that the loss of total value by 2020 would be LKR 31 million in the desiccated coconut sector and LKR 11 million in the coconut oil sector due to climate change impacts. Insufficient nut production has been the major problem that has prompted a negative impact on other value-added products. According to EDB (2019) the sector earns a competitive advantage due to the blend of indigenous and modern technologies used for processing. The coconut value chain is presented in Figure 2 (Pathiraja et al., 2017a).

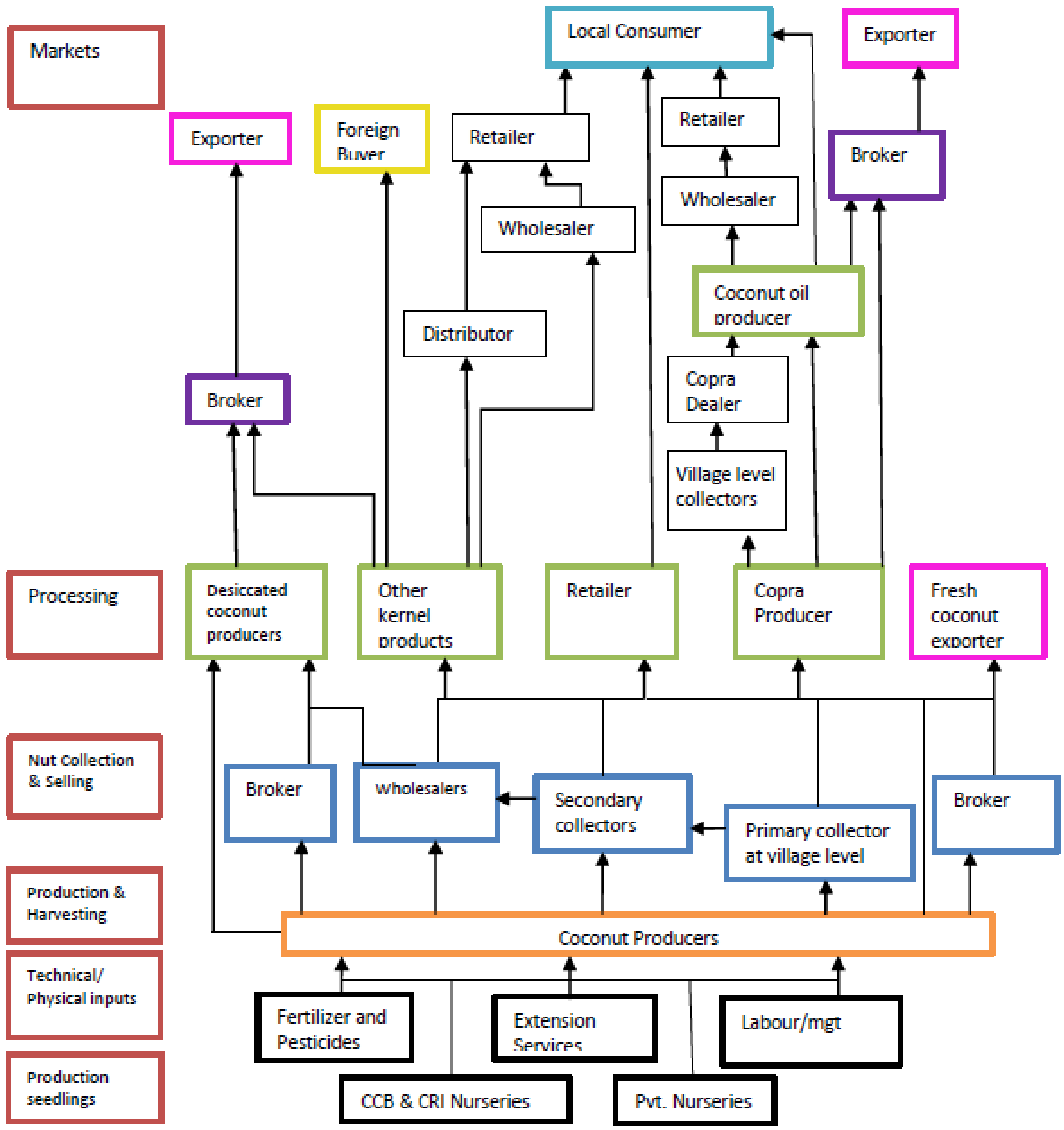


Figure 2. Coconut value chain

Source: Pathiraja et al. (2017a).

Investments for mill development and processing research are provided by the government. Technology improvement and subsidies help to increase production (Pathiraja et al., 2017). However, a study of fresh coconut and oil markets by Abeysekara et al. (2020) revealed that oil has become an inferior good based on their analysis. This could be attributed to availability of many different cheap oil substitutes in the market with negative nutritional and health implications.

2.3.3 Coconut consumption

According to EDB (2019), there are various different coconut kernel products such as fresh coconut, coconut water/king coconut water, edible copra, virgin coconut oil, desiccated coconut, RBD coconut oil, coconut flour, coconut butter, liquid coconut milk powder, coconut milk, coconut cream, defatted coconut, coconut amino, coconut sugar and vinegar. As indicated by CDA (2016), 15%, 5% and 70% of calories, protein and lipid requirements of dietary requirements of Sri Lankans are supplied by coconut which account for nearly 60% of total nut production. The remaining 40% of nut production is targeted for the export market through various value-added products. However, it stated that present-day coconut production is inadequate to satisfy both domestic and industrial requirements. According to Pathiraja et al. (2017), the 5% total predicted loss of total value of the industry would be borne by wholesalers, up to two-thirds of the total impact, followed by domestic coconut and coconut oil consumers.

2.3.4 Climate change adaptation of the coconut supply chain

According to Ranasinghe (2019), lack of awareness on adaptation measures and lack of drought- and heat-tolerant varieties limits the ability to face adverse climatic conditions. According to Pathiraja et al. (2019), Sri Lankan agriculture could be facing increased production risk due to potential climate change impacts that are attributed to the limited capacity to develop resilience measures. Therefore, Pathiraja et al. (2019) proposed some key measures to mitigate negative effects of climate extremes. Among those measures a systematic methodology for fertilizer application, soil moisture conservation practices, irrigation and use of heat-tolerant cultivars were highlighted. They further noted that 41% of the coconut growers were practising moisture conservation with husk or coir dust pits.

2.4 IMPACTS OF CLIMATE CHANGE ON THE VEGETABLE SUPPLY CHAIN

The vegetable subsector in Sri Lanka occupies an important role from economic, social and nutritional perspectives. It plays an important role in the Sri Lankan economy in terms of its contribution of 10% to agricultural GDP (CBSL, 2019a). About 300,000 agricultural operators predominately from Nuwara Eliya and Badulla districts cultivate vegetables in Sri Lanka (DCS, 2019a). The vegetables are categorized into upcountry vegetables and low country vegetables mainly based on the elevation of the area in which the cultivation is done.

The vegetable requirements of the country are domestically produced except for a small quantity amounting to about 9% of the requirement that is imported (Table 3). Per capita availability ranged from 134 kg to 146 kg for the period 2013 to 2017 (DCS, 2019b).

Table 3. Vegetable production and imports from 2013 to 2017

Year	Production (′000 tonnes)	Imports (′000 tonnes)
2013	3,160	279
2014	3,022	241
2015	3,001	261

2016	3,072	349
2017	2,962	334

Source: DCS (2019a).

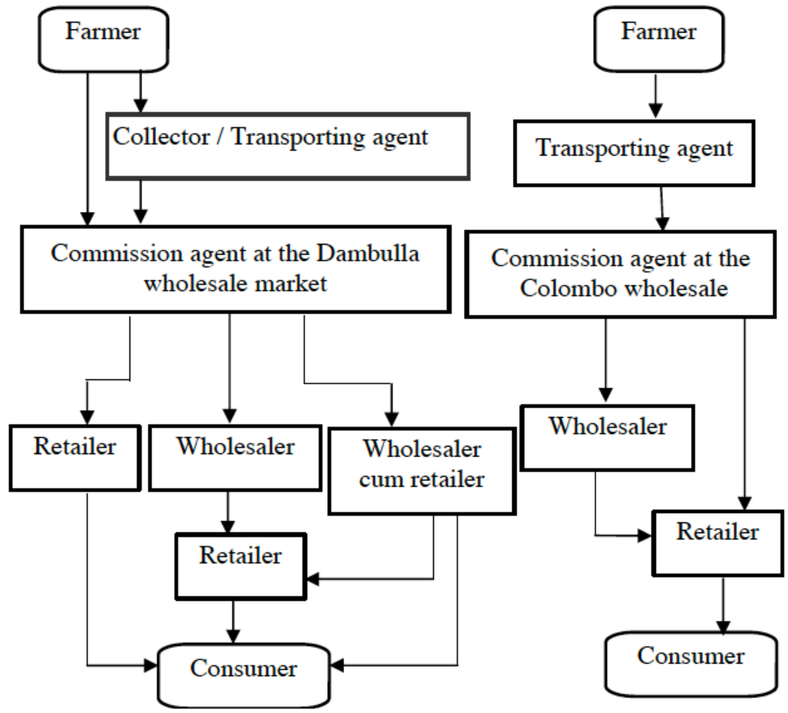


Figure 3. Traditional vegetable supply chain

Source: Perera et al. (2011).

The traditional vegetable supply chain involves collectors and transporters based in the production area collecting and moving produce to regional dedicated economic centres or directly to economic centres in Colombo. The produce then moves to wholesalers and retailers and finally to the customer. Currently there are 14 dedicated economic centres in the country, of which five are located in Colombo District. With the emergence of supermarkets, more efficient alternate supply chains have emerged (Abeysekara & Abeysekara, 2007). The structure of the supply chain to a larger extent depends on the downstream actors such as supermarkets, exporters and processors. Supermarkets with a small number of outlets procure their requirements from the wholesale markets and dedicated economic centres. Supermarkets with larger numbers of outlets procure from vegetable collectors who deliver to their central processing units. Supermarkets with an extensive network of outlets have set up regional vegetable collecting centres located close to vegetable farming areas. Farmers as well as vegetable collectors bring vegetables to these collecting centres (Perera et al., 2011).

Exporters and processors use spot markets, contract suppliers and contract farmers as their major procurement sources. Exporters mainly use spot market and contract suppliers while processors use all three major channels to procure fruits and vegetable requirements (Esham & Usami, 2006).

2.4.1 Vegetable production, storage, processing distribution, wholesale and retailing

The vegetable subsector in Sri Lanka is as equally affected by climate change as other subsectors in agriculture hence, vegetable supply chain activities on farm and off farm are affected by rainfall variability, increase in temperature and elevated CO_2 concentration. However, there is no published literature on the direct impact of climate change on production and other supply chain activities in the Sri Lankan context.

Postharvest losses in the fruit and vegetable sector are extensive, as significant amounts of fruit and vegetables are channeled through traditional marketing channels involving poor handling and transport. Major reasons for postharvest losses include unsuitable harvesting practices, malpractices during transportation, improper packaging and careless handling (Gunarathna et al., 2020). For instance, upcountry vegetables such as leeks and cabbage reported postharvest losses as high as 43% to 44% (Dharmathilake et al., 2020). These products are transported in open trucks using poor quality boxes or tightly stacked plastic bags (Esham et al., 2018). The highest amount of postharvest loss occurs during transport which is nearly 75% of the total loss Jayathunge et al., 2003 (as cited in Dissanayake et al., 2017). A limited volume that is supplied to supermarkets undergoes proper postharvest handling as the supply chains of supermarket chains compared to traditional supply channels are more efficient and effective (Kodithuwakku & Weerahewa, 2014).

Environmental conditions such as high temperature and high relative humidity are likely to contribute to postharvest losses of poorly handled perishables such as fruits and vegetables (Esham et al., 2018). Moreover, the shelf life of fruits and vegetables is reduced; the rule of thumb is for reduction of each 10°C of pulp temperature, the shelf life of fruits and vegetables is prolonged by two to three fold (Moretti et al., 2010).

The major procurement channel of fruit and vegetable processors is smallholder contract farmers (Esham & Usami, 2006). Because of their vulnerability to inconsistent weather conditions, these supply channels are not considered reliable to ensure consistent supply (Esham et al., 2018). This situation creates supply uncertainty to the fruit and vegetable processing industry. The main reason for the industry to operate under capacity is attributed to fluctuation in fruit and vegetable supplies (Esham & Usami, 2006). There are situations in which processors are compelled to operate under capacity as a result of short supply of raw materials and high prices following periods of extreme weather events (Esham et al., 2018).

2.4.2 Vegetable consumption

All South Asian countries including Sri Lanka consume fruits and vegetables below WHO recommendations (Jayawardena et al., 2020). In Sri Lanka, consumption of vegetables is reported to be considerably low (Jayathissa, 2014) even though an average household spends 8% out of total household food expenditure on vegetables (CBSL, 2019b). According to a dietary survey by Jayawardena et al. (2013) a significant proportion of the Sri Lankan population does not consume a balanced diet; the daily intake of fruits, vegetables and dairy portions is significantly below the national recommendations (Jayawardena et al., 2013). Low daily intake of fruit and vegetables can be attributed to low purchasing power, seasonality of market prices and poor awareness of the nutritional benefits (Jayawardena et al., 2013).

Evidence shows that there is a negative correlation between dietary diversification and prices of food in developing countries (Brinkman et al., 2010). Accordingly, a study in Sri Lanka showed that income was a major determinant of fruit consumption (Weerahewa et al., 2013). Therefore, it is more likely that low-income groups are unable to afford fruits and vegetables as they are relatively expensive. At times of extreme weather, prices of fruits and vegetables normally increase making these food items unaffordable for the low-income groups, especially the urban poor. For instance, heavy rains across the country throughout May 2018 significantly damaged vegetable cultivation in both up-country and low-country areas, resulting in low supply conditions, increasing vegetable prices from end May 2018 onwards (CBSL, 2018). There is strong evidence to show how extreme weather events in vegetable production areas translate into vegetable price escalation (Esham et al., 2018).

Climate change adaptation in the vegetable sector has received little attention among researchers as there is a dearth of research on climate change adaptation related to both upcountry and low country vegetable supply chains.

2.5 IMPACTS OF CLIMATE CHANGE ON THE FISH SUPPLY CHAIN

The marine fisheries sector plays an important role in Sri Lanka's economy as a major source of income for coastal communities. Further it contributes to employment and foreign exchange earnings. The fisheries sector contributed 1.2% to Gross Domestic Production in 2018 and is the source of livelihood for 2.7 million coastal communities (NARA, 2019). The marine fisheries sector in Sri Lanka consists of both coastal and offshore fisheries. The country has an exclusive economic zone (EEZ) of 517,000 km^2 and a continental shelf of 30,000 km^2. About 83% of the total captured fisheries production is derived from marine fisheries (Table 4). Fish is a major nutritional source for both coastal and urban communities and provides 60% of animal protein requirements (NARA, 2019).

Marine fish reach consumers through diverse channels. The domestic end market channels consist of Ceylon Fisheries Cooperation (CFC) outlets, supermarket chains, urban and rural retail fish outlets and fish vendors. Urban wholesale markets, such as the Central Fish Market Complex in Peliyagoda play an important role in distributing marine fish to retailers and consumers in Colombo. The CFC has set up 103 retail fish outlets island wide and new outlets are proposed to be established in 20 cities (MFARD, 2019).

Table 4. Fish production in Sri Lanka (tonnes)

Sub sector	2014	2015	2016	2017	2018
Offshore/deep sea	180,450	183,870	182,830	189,720	190,350
Coastal	278,850	269,020	274,160	259,720	249,020
Total marine	459,300	452,890	456,990	449,440	439,370
Inland & aquaculture	75,750	67,300	73,930	81,870	87,690
Total fish production	535,050	520,190	530,920	531,310	527,060

Source: Fisheries Statistics 2019, Ministry of Fisheries and Aquatic Resources Development.

It is well known that climate change has brought about far-reaching consequences for fisheries ecosystems by shifting stocks and lowering fish productivity thereby altering the livelihoods of communities dependent on fisheries. According to the IPCC special report: The Ocean and Cryosphere in a Changing Climate (SROCC), emissions of carbon due to human activities are causing ocean warming, acidification and oxygen loss with implications for fish production.

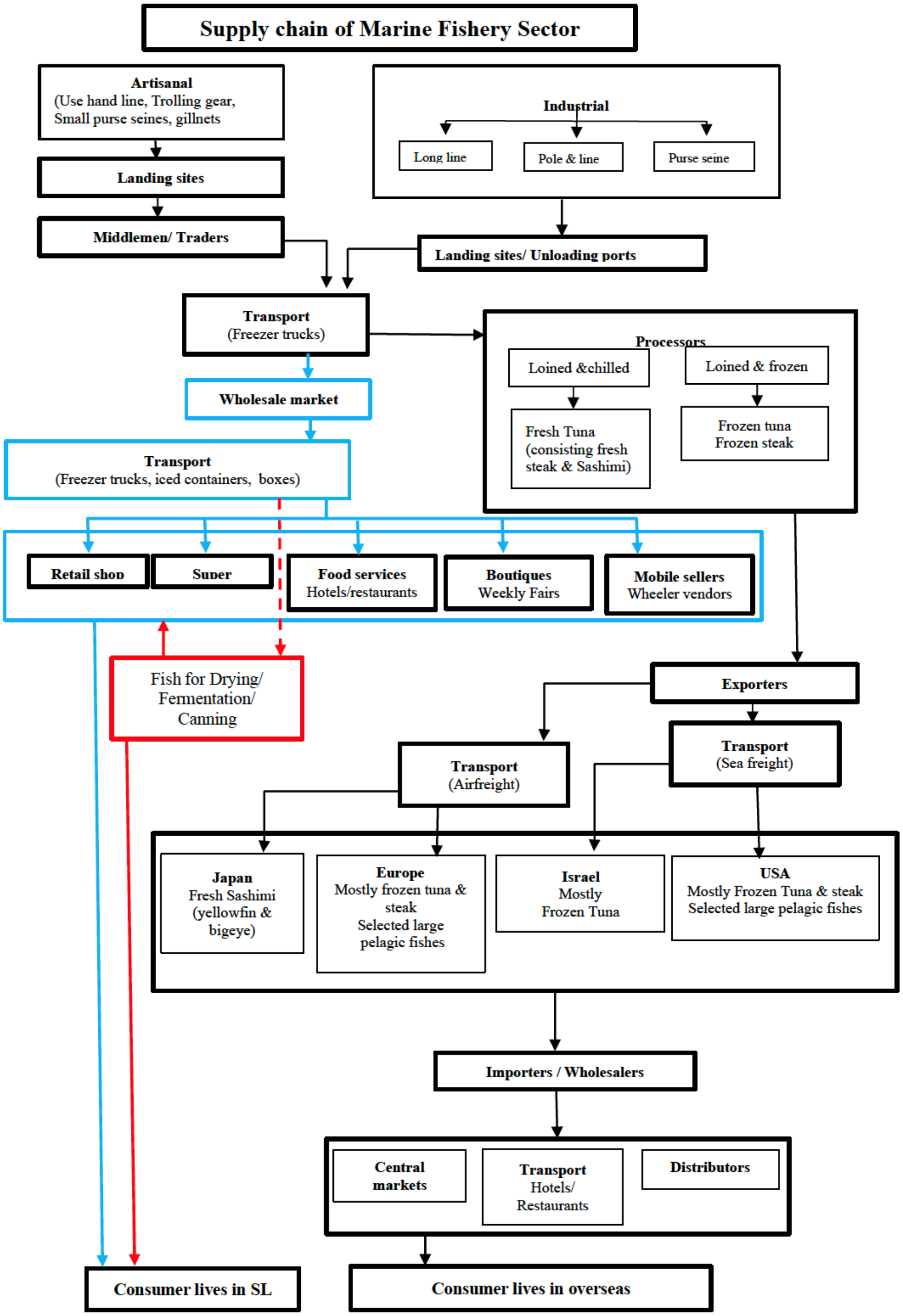


Figure 4. Marine fish supply chain

Source: Edirisinghe et al. (2019).

The same report projects that by the end of the century, the ocean is very likely to warm for low emission scenarios by 2% to 4% and for high emission scenarios by 5% to 7% compared with the observed changes since 1970 (Bindoff et al., 2019). Warming of the tropical Indian Ocean is taking place at a faster rate compared to other tropical oceans (Gnanaseelan et al., 2017). The climate model projections for the Indian Ocean indicate that sea surface temperature by 2080 is likely to rise by 0.69°C and 2.6°C for low emissions and high emissions scenarios respectively with implications for fish production (Akhiljith et al., 2019). It is projected that in some tropical exclusive economic zones, the maximum catch potential will decline by up to 40% by the mid-century (Lam et al., 2020). Another modeling result suggests that in the South Asian regions projected capture in 2030 is likely to be 31% lower than the baseline scenario with climate change mitigation (Msangi et al., 2013).

It is reported that the global mean sea level has increased by 0.19 metres during the last century and could potentially increase by 1 metre by the end of the century (Pfeffer et al., 2008; Church and White, 2011).

Sri Lanka's marine fisheries sector vulnerability to impact of climate change is ranked 35th among 147 countries and falls into the first quartile of rankings; the vulnerability scores reveal that adaptive capacity is significantly low for countries belonging to the first quartile (Blasiak et al., 2017). Sri Lanka is also vulnerable to climate change in terms of sea-level rise and ocean acidification which could lead to loss and changes of coastal habitats, breeding grounds and species distribution (Athulathmudali et al., 2011). According to Senaratne et al. (2009), changes in distribution, alteration of species composition, growth and reproduction of fish stock, damages to fishing infrastructure and disturbance to fishing activities are the results of increase in oceanic temperature, changes in rainfall regimes, sea-level rise and extreme weather events such as storm surges.

Sea-level rise can impact on coastal fishing in Sri Lanka with implications for coastal fish production which contributes approximately 60% and 50% to marine fish production and total national fish production. Hence, climate change will impact fishing operations directly, through sea-level rise, changes in marine ecosystems and frequency of extreme weather events.

2.5.1 Fish production

Coastal fishing in Sri Lanka depends on monsoon climate patterns, except for a few large commercial operators with modern facilities, for others fishing is a seasonal occupation (Anon, 2008). The main coastal fishing season of the southern fishing belt lasts from November to March. In the peak season daily fishing operations take place. The off season coincides with the southwest monsoon from May to September when the seas become rough. During this period fishing operations are only undertaken two to three days per month. Shift in rainfall pattern has disturbed the fishing seasons with implications for coastal fish production and fish varietal composition (De Silva, 2016). The southern fishing belt is often affected by extreme climate conditions which have become the norm resulting in loss of number of fishing days (Weddagala et al., 2018). The decline in marine fish production in 2015 compared to the previous year was attributed to extreme climate conditions (Arulanathan, n.d.). Deep-sea fish production declined by 9.2% compared to 2017 owing to frequent cyclonic conditions in the

Indian Ocean; several multiday fishing trips were cancelled based on weather warnings (CBSL, 2019). Simulations indicate a strong decrease of biomass after the mid-21st century (Dueri et al., 2014).

The marine fishery is the major contributor to national fish production (Table 4). There are 15 marine fisheries administrative districts in the country. Of them, Puttlam, Hambantotta, Galle and Kulutara districts are dominant and contributed over 52% to the total marine fish production of the country in 2018 (Table 5). However, some of these areas such as Puttlam District are identified as coastal areas highly vulnerable to sea-level rise (Mawilmada et al., 2010). Figure 5 depicts the vulnerable fish-producing areas in the country.

Skipjack tuna and yellow fin tuna and other tuna varieties are the major contributors to the total marine fish production in the country. Model projections of climate change impacts on Indian Ocean tunas indicate that skipjack tuna is projected to move to higher latitudes with implications for local fish production.

Fishing boats and gear are also affected and damaged due to extreme weather events.

Fibreglass Reinforced Plastic (FRP) boats are the most common type of boats used at the national level. FRPs occupy 48% of the national fishing fleet (MFARD, 2018). FRP boats are highly vulnerable to extreme weather such as high winds and storms, which have become increasingly common in recent times (De Silva, 2016). Often, fisherman deaths are reported during the monsoon period due to rough seas. In 2013, 54 fisherman lost their lives due to inclement weather (LBO, 2013).

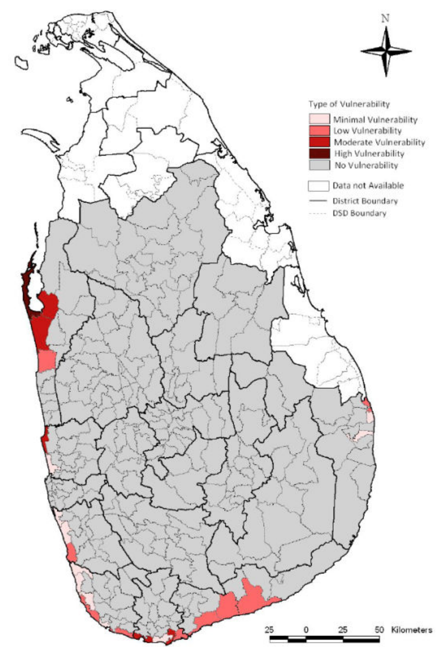


Figure 5. Marine fishery sector exposure to sea-level rise

Source: Mawilmada et al. (2010).

Table 5. Marine fish production by major fish-producing districts and Colombo districts in 2018 (tonnes)

District	Annual production	As % of national production
Puttlam	65,340	15
Hambantotta	64,230	15
Galle	54,100	12
Kalutara	41,750	10
Jaffna	41,070	9
Trincomalee	34,300	8
Colombo	4,650	1
Other districts	133,930	30
Total	439,370	100

Source: Fisheries Statistics 2019, Ministry of Fisheries and Aquatic Resources Development.

2.5.2 Fish storage, processing, wholesale and retail

Fish storage and processing is likely to be impacted due to extreme weather in terms of damage to processing facilities and high energy cost for cold storage during hot days. Extreme weather conditions can contribute to postharvest losses. It is reported that the postharvest losses of marine fisheries have reached a high level 40% (Amarasinghe, 2020). The fishery harbours, anchorages and landing sites are poorly equipped and lack basic facilities (Athuda & Chandraratne, 2020). Most of the fish landing sites lack chilled storage and ice supplies which contributes to the postharvest losses (Edirisinghe et al., 2018).

Extreme weather also impacts small-scale fish processing that uses traditional methods such as salting, drying and smoking. These activities are badly affected by unusually heavy rains (De Silva, 2016). It is reported that heavy rains often badly affected harvest quality, operations of mobile retailers and small-scale retail outlets (De Silva, 2016). Frequent wet weather conditions and increasing temperatures badly affect the storage quality of fresh fish and fishery products (De Silva, 2016).

2.5.3 Fish consumption

Fish are of major nutritional importance for urban communities as 52% of animal protein is derived from seafood (Gephart et al., 2017). The Medical Research Institute (MRI) of Sri Lanka recommended that an average per capita consumption of about 60 g of fish per day or 21.9 kg per year would be satisfactory to ensure adequate nutrition (Fisheries Sector Development Strategy of Sri Lanka, 2010). However, per capita fish consumption in the country is far below the requirement and stands at 11.8 kg out of which 9 kg or 76% comes from marine fish (Fisheries Statistics, 2019). As fish production is highly sensitive to climate variability and natural disasters, fish supply can be heavily impacted by natural hazards. The December 2004 tsunami is a good example for illustrating how shocks from a natural disaster can impact the seafood system in terms of affecting the per capita supply with possible impacts on local food security (Gephart et al., 2017). Adverse weather conditions have often contributed to price rises in the main fish market in Colombo (FAO, 2019). Trend analysis has revealed that fish prices show a seasonal pattern where prices tend to be high mid-year (Perera et al., 2016). The household share of fish expenditure has increased over time for both rural and urban households. However, fish have been considered a luxury commodity by both rural and urban households over time (Pallegedara, 2019).

2.6 IMPACTS OF COVID-19 ON COLOMBO CITY REGION FOOD SYSTEMS

The Covid-19 outbreak emerged in Wuhan city of China in 2019 and had developed into a pandemic by March 2020. By April 2020 more than 50,000 deaths had been reported while 2.5 million people had become infected with the virus (CBSL, 2020). Sri Lankan authorities adopted early measures to control the pandemic through rigorous quarantine measures, hospitalizing infected people, lockdowns, curfews and travel restrictions that led to a success story. However, the impact of the pandemic on the country's economy was of significant magnitude. Currently, Sri Lanka is facing the second wave of the pandemic leaving a significant chaotic situation in the economy. According to media reports, there were about 3 million kg of vegetables stuck in Dambulla economic centre in early November 2020 and about 300,000 kg of fish catch remained unsold in the fish market due to the pandemic.

It is obvious that there had been a negative impact on the domestic economy due to lockdowns, curfews and travel restrictions. Closure of seaports and airports had direct impact on the tourism sector, export, foreign trade and allied employment. Further, disruptions to the food supply chains had multiple impacts concurrently on both the rural and national economy.

Daily paid and casual workers lost their incomes and livelihoods prompting the government to intervene by individual disbursement of LKR 5,000 to safeguard their livelihoods. The significant impact of Covid-19 on employment is evident across the country. Out of total employment, about 60% works in the informal sector of which an estimated 1.9 million are daily wage earners. There are other vulnerable groups of people such as the poorest of the poor, elderly citizens and individuals with special needs affected by the pandemic (CBSL, 2020).

Laborde et al. (2020) emphasized four features in the food supply chain to reduce the impact of Covid-19 restrictions. Sri Lanka followed suit including allowing farmers to work in their production grounds, introducing additional alternative food transport systems, adjusting packaging for most perishable products and managing public food relief programmes.

Due to Covid-19, supply chain nodes of agricultural products have become more vulnerable causing negative impacts on food availability (Kumar et al., 2020). Figure 6 shows the potential Covid-19 impact pathways applicable to countries in the South Asian region (Babu et al., 2020). The nodes in the given impact pathways show how both production ends and consumer ends are affected due to overall impact. They further proposed a number of strategies such as proper farm mechanization, an 'infection safe' distribution system for both input and output in agriculture, new labour management tools, credit facilities and so forth (Babu et al., 2020).

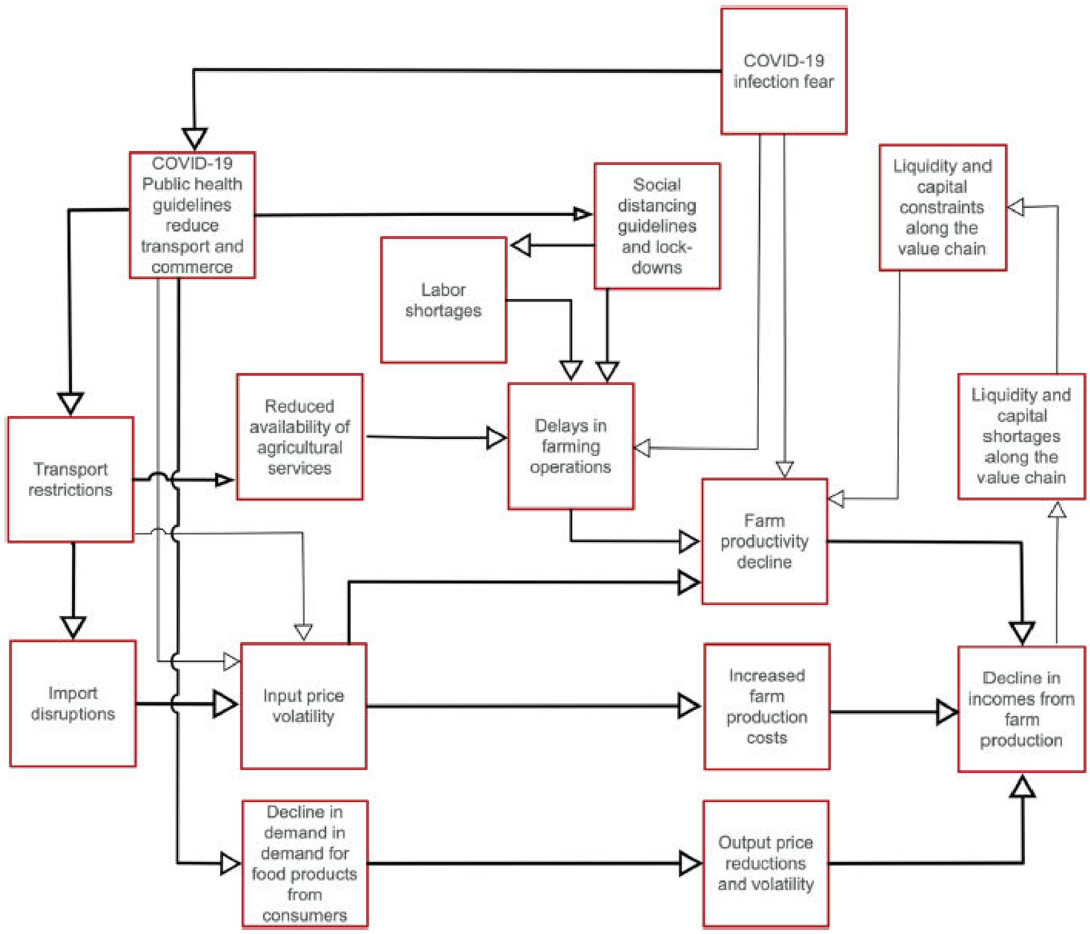


Figure 6. The potential Covid-19 impact pathways that may affect food production systems in South Asia

Source: Babu et al. (2020).

Béné (2020) highlighted the most prominent household resilience measures for improving food security to face the Covid-19 pandemic. They indicated certain principles to develop food system resilience and suggestions for certain interventions. The list includes diversification substitution, entrepreneurship, cooperation, competition, connectivity/farmer–buyer relationships, insurance, inclusiveness, cash transfer, psychosocial factors and subjective resilience. One of the most practical options available to ensure urban food security is to promote the urban agriculture. Vertical gardens, rooftop gardens and other protected agricultural techniques may help to ensure household food supply, especially vegetables and fruits (Pulighe & Lupia, 2020).

Harris et al. (2020) investigated the effects of pandemic events on production, prices, sales and income status of vegetable farmers in India. Most farmers reported negative impacts on given supply chain nodes that ultimately influenced their income. They also reported price reductions. The most prominent demand side shock on food supply chains was the panic buying of essentials that led to a drastic change in consumption patterns (Hobbs, 2020). Labour shortages were common problems in most production activities. Further, transportation networks were seriously affected.

Lockdowns prevented daily paid workers engaging in their jobs which had serious impacts on their purchasing power. However, they continued to consume food and household resources to sustain their lives during the pandemic (Devereux et al., 2020).

Galanakis (2020) emphasized that the number of people affected by food shortages would double unless authorities acted immediately with specific strategies such as immediate assistance to agricultural production, widening emergency food assistance programmes and rectifying the bottlenecks of food logistics. The Sri Lankan Government eased restrictions on mobility of farmers, workers, agricultural inputs and produce during the height of the pandemic to prevent food shortages in the country.

CHAPTER 3 METHODOLOGY

3.1 STUDY AREAS

The Colombo CRFS considers rural-urban linkages including foodsheds that feed Colombo. As Colombo receives its bulk of food supplies from other regions of the country, the study area was extended to major paddy, coconut, vegetable and fish producing regions such as Ampara, Anuradhapura, Polonnaruwa, Kurunegala, Nuwara Eliya, Badulla and the southern and western fishing belts, especially to explore the production nodes of the food supply chains. The assessment focused on four supply chains, viz., fish, rice, coconut and vegetables (upcountry and low country vegetables).

3.2 RISK AND VULNERABILITY ASSESSMENT FRAMEWORK

This research is guided by the risk assessment framework specified in the IPCC Fifth Assessment Report (AR5). In this framework, risk (R) is expressed as a function of three components namely hazard (H), exposure (E) and vulnerability (V). Risk results from the interaction of vulnerability, exposure and hazard (Figure 7).

$$R = f\,(H, E, V)$$

Hazard is defined as "*the potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure*". Hazard is an external element representing climate-related stress.

Exposure is "*the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected*". It can be measured in terms of proportion or quantity of assets such as land, stakeholders and volume of local production that is exposed.

Vulnerability is "*the propensity or predisposition to be adversely affected. Vulnerability includes two components: adaptive capacity and sensitivity*". These are recognized as intrinsic attributes of a system, which predispose a system to be adversely affected by any harm. The first component of vulnerability, adaptive capacity, is "*the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences*". The second component of vulnerability is sensitivity. Sensitivity is the "*degree to which a system or species is affected, either adversely or beneficially by climate variability or change*". Vulnerability is characterized as an internal property of a system.

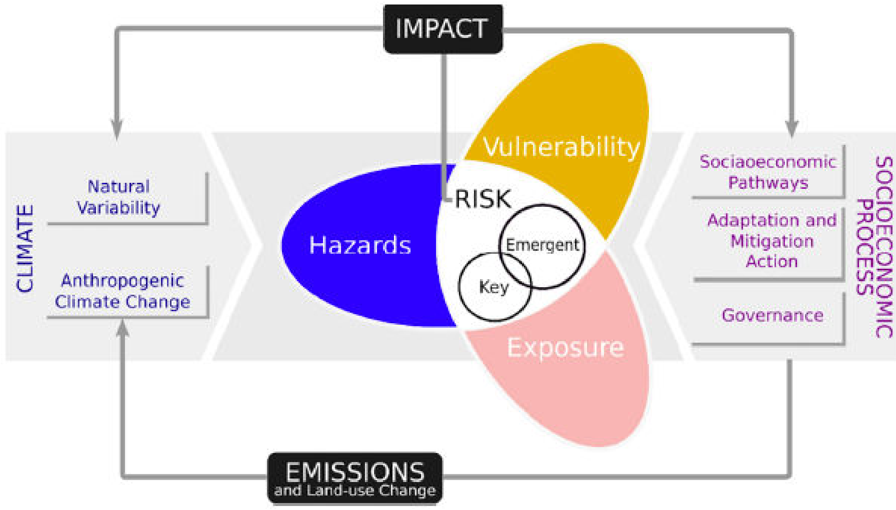


Figure 7. The contributing factors of risk

Source: Adapted from IPCC AR5 (2014).

3.3 DATA COLLECTION APPROACH

In this study, a mixed approach was used to collect data consisting of an extensive web-based search of climate change impact-related media coverage over six years (2015-2020), secondary data compilation, literature and document review, and expert consultation. The data collection methods and their purpose are summarized in Table 6.

Table 6. Data collection methods and purpose

Data collection methods	Purpose
Literature review and document analysis	To develop a food system profile and refine variables relevant to vulnerability assessment
Secondary data compilation through content analysis and published data sources	Data for developing vulnerability indices and measures
Primary data from stakeholders using questionnaire schedules	Data for verifying climate hazards, exposure, sensitivity and adaptive capacity and developing indices
Expert validation	Validate vulnerability indices and measures

Source: Authors

Table 7 indicates the number of news items collected over the period of six years under each supply chain.

Table 7. Distribution of news items under each supply chain

Sector	No of news items
Fishery	195

Paddy	175
Vegetables	133
Coconut	172
Total	675

3.4 CONTENT ANALYSIS

The web content analysis was used to capture climate events and Covid-19 pandemic impacts reported in the mainstream electronic media in Sri Lanka over six years. The individual events identified were used to determine the nature of the hazard, exposure and vulnerability. The hazards were corroborated with meteorological data and Covid-19 data while exposure and vulnerability were corroborated with climate data and other relevant secondary data. The Figure 8 summarizes the content analysis process.

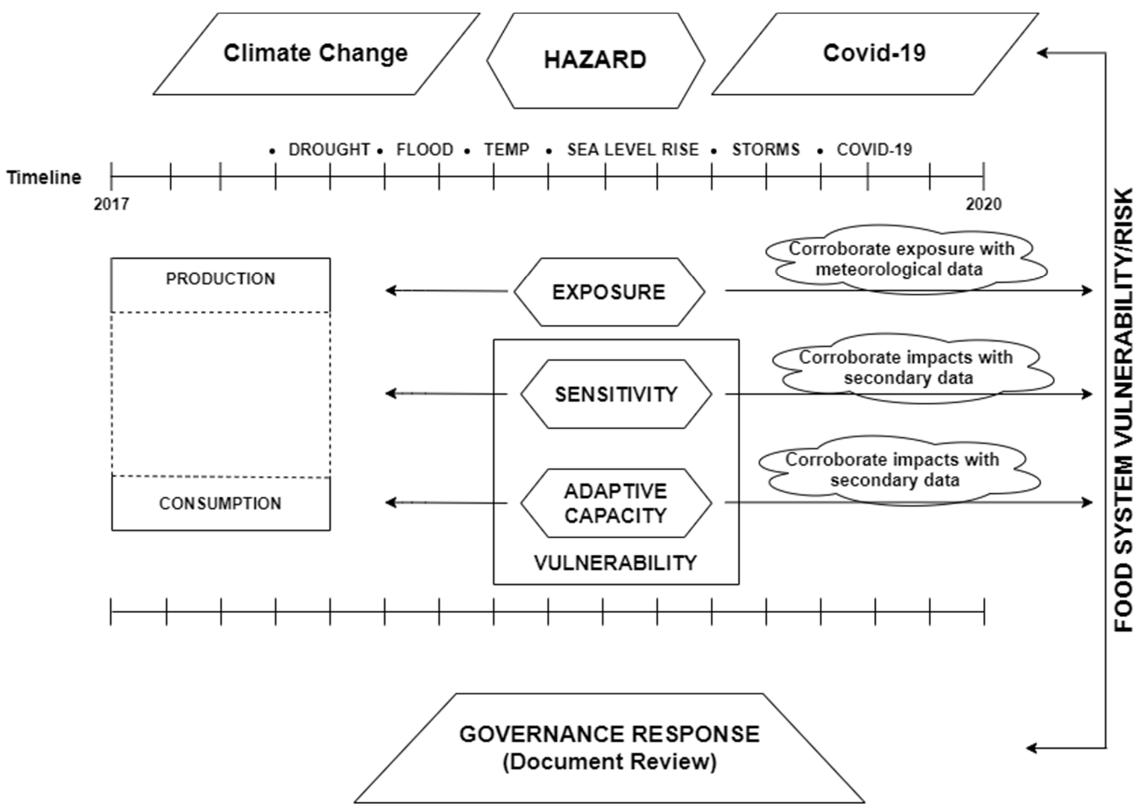


Figure 8. Framework for content analysis

Source: Authors

The data captured through web-based content analysis were used to identify (1) climate hazards such as floods, landslides, drought, temperature rise, sea-level rise, storms, cyclones, etc., and Covid-19 hazards; (2) the exposure of relevant nodes to climate and Covid-19 hazards; (3) climate and Covid-19 impact on production, assets, infrastructure and socio-economic status to assess sensitivity; (4) the capacity of the nodes to withstand the impact of hazards; and (5) the responses of supply chain actors and governance actors.

3.5 DATA

Initially, it was intended to collect data, both published and unpublished, from the following institutions by means of questionnaire schedules (Table 8). However, due to Covid-19 restrictions it was not possible to collect data from these sources as planned.

Table 8. Proposed data source and description

Supply chain	Data source
Fish	Ministry of Fisheries and Aquatic Resources, Department of Fisheries and Aquatic Resources, Ceylon Fisheries Corporation, Ceylon Fisheries Harbour Corporation, Fishers associations/cooperatives in the south
Paddy rice	Paddy Marketing Board, mills Fertilizer Secretariat, Ministry of Agriculture, private mills, the Co-operative Wholesale Establishment, multipurpose co-operative societies, supermarket chains, retailers, the Paddy Wholesalers' Association, Marandagahamula Wholesale, Narahenpita Dedicated Economic Centre, Department of Co-operative Development
Coconut	Coconut Development Authority/Coconut Auction – Colombo, coconut wholesalers, coconut collectors – Kurunegala, Coconut Cultivation Board, Coconut Research Institute, Sri Lanka Coconut Producer's Co-operative
Vegetables	Supermarket chains, retailers, dedicated economic centres (Narahenpita, Dambulla, Keppetipola)
Common for all	Fertilizer Secretariat, Agrarian Insurance Board, Disaster Management Centre, Department of Meteorology, National Disaster Relief Service Centre, Climate Change Secretariat/Ministry of Environment and Wildlife Resources, Nutrition Division/Ministry of Health. Hector Kobbekaduwa Agrarian Research & Training Institute (HARTI), Agrarian Insurance Board

Source: Authors

3.6 ASSESSMENT OF RISK AND VULNERABILITY

The elements of risk assessment, hazards, exposure and vulnerability (sensitivity and capacity) were delineated from the content analysis, secondary and primary data for each value chain node of the four commodities. Based on availability of data a numerical scale was used to evaluate the content analysis results and available secondary data. Scores were assigned for supply chain nodes for which data were available. The numerical scales enabled measuring the intensity of the risk/vulnerability dimensions. For instance, 0 was proposed when there was no impact, a higher number was proposed when the intensity was extensive. The scores assigned to supply chain nodes of rice, coconut, vegetables (up and low country) were analyzed on a seasonal basis (Yala and Maha) from 2015 to 2020 while for fish on a monthly basis. The scores were used to develop risk and vulnerability indices. The best seasons (seasons with minimum impact of hazards) were used as benchmarks to compare the risk and vulnerabilities of the respective supply chain nodes.

Following the AR5 theoretical framework we propose the following operationalization procedure to quantify the effect of climate hazard on CRFS.

$$H_{ijk} \in Z^{-} : H_{ijk} \in [0,-4]$$

Where, H_{ijk} is an integer (Z) between zero and -4 (0 = no effect (benchmark), -1 = damage and loss to property, -2 = injury, or other health impacts, -3 = loss of life, -4 = loss of life and any stated damage, that indicates the size of the hazard in j^{th} sector at i^{th} time on k^{th}node of food supply. Then it was re-classified as Severe = loss of life plus other damages; very strong = loss of life; strong = injury or other health impacts; moderate = loss of property. The vulnerability scores were calculated by assigning scores to the two subcomponents of the vulnerability: adaptive capacity and sensitivity separately based on available information from the content analysis, secondary and primary data (Table 9). The attributes of the node of the supply chain as well as the hazard impact were matched to arrive at a sensitivity score. Scores were assigned for the capacity based on content analysis, secondary and primary data. Finally, the scores of sensitivity and capacity were aggregated to arrive at a vulnerability score.

Table 9. Operationalization of vulnerability (illustration)

Score: Inherent internal factors	Score: Climate event-specific internal factors	Sensitivity	Capacity	Vulnerability
-1	-1	-2	1	-1
-1	0	-1	1	0
0	-1	-1	1	0
0	0	0	1	1
-1	-1	-2	-1	-3
-1	0	-1	-1	-2
0	-1	-1	-1	-2
0	0	0	-1	-1

Note: Inherent internal factors: poverty head count index; climate event-specific internal factors: severity of the impact.

Sensitivity score: will be an aggregate of the scores assigned for the above two factors.

Capacity score: 2 = early warning+ compensation + aid; 1 = any evidence support/relief; -1 = no capacity.

Vulnerability score: highly vulnerable = less than or equal to -4; moderately vulnerable = less than or equal to -1; less vulnerable = more than or equal to 0.

Source: Authors

Scale for measuring exposure: If 100% of the population, assets and infrastructure was affected, the exposure score would get the highest possible negative score of -4. On the other extreme the lowest possible would be zero i.e., no exposure. The rating scale used was as follows: less than or equal to 25% = -1; more than 25% up to 50% = -2; more than 50% up to 75% = -3; more than 75 up to 100% =-4.

Scale for measuring sensitivity: The sensitivity score would take into account inherent internal factors assessed in terms of the poverty head count index. The poverty head count index was assigned scores as follows:
Less than or equal to 5 = -1; 5 up to less than or equal to 10 = -2; 10 up to less than or equal to 15 = - 3; above 15 = -4.
The climate event-specific internal factor was measured based on its effect on the system thus the score was determined as follows:
If the effect was adverse, the score was -1; no effect = 0; beneficial effect = 1.
The final sensitivity score would be an aggregate of the above two scores.

Scale for measuring capacity: The capacity score would take into account two indicators; capacity to withstand the impact of the hazard and the proportion of Samurdhi (prosperity) Programme recipients to the poor in the DSD or district.
Capacity scores were assigned as follows:
Early warning+ compensation + aid = 2; any evidence support/relief = 1; no capacity = -1. The score for Samurdhi was calculated based on the proportion of Samurdhi recipients to the total poor population. If the percentage was < 100% -1; otherwise, 1. The final capacity score would be an aggregate of the above two scores

Scale for measuring vulnerability: The vulnerability score was arrived at by aggregating sensitivity and capacity scores. The scores were categorized as follows:
highly vulnerable = less than or equal to -4; moderately vulnerable = less than or equal to -1; less vulnerable = more than or equal to 0.

Table 10 summarizes the variables used for scoring.

Table 10. Variables used for scoring

Dimension	Variable (tentative units of measurements)
Hazard	Monthly rainfall Daily minimum and maximum temperature Drought events Flood events Landslides Strong winds
Exposure	Population DSD-wise in Colombo city region Exposed population Exposed roads Production loss
Sensitivity	Poverty head count index Climate specific internal factors
Capacity	Availability of early warning (rating score) Crop insurance Compensation

Samurdhi beneficiaries (score)
Climate change adaptation (rating score)

3.7 ASSESSMENT OF FOOD SYSTEM GOVERNANCE

Food system governance is known as a system of rules, authority and institutions that coordinates, manages, or guides food systems to achieve food security, enhance resilience, facilitate adaptation, or instigate transformation. Governance will involve decision-making by food system stakeholders related to food system activities from production to consumption. Governance will be considered as more than the formal functions of government agencies but also include market players, larger companies, trade networks and non-state actors such as civil society organizations. The governance assessment will aim at the analysis of institutions, laws and regulations affecting the food system. Table 11 shows core areas covered to understand food system governance. Data and information to understand governance are based on review of available documents and content analysis.

Table 11. Core areas assessed under governance

Core areas governance	Description
Climate change	Climate change policies, strategies and plans relevant to food systems at national and city region levels
Early warning	Status of early warning systems, responsible agencies and its application
Risk management and insurance	Development of agricultural insurance, coverage and institutions

3.8 DATA PROCESSING AND ANALYSIS

The data consisted of content analysis, secondary data and a limited amount of primary data. They included published reports, literature review and published data channeled through content analysis. Two databases were developed for secondary/primary and content analysis data. A standard coding was adopted to enter data in a digital database. Rigorous data cleaning was carried out before the standard analysis was performed. The data were analyzed to derive risk/vulnerability indices for individual supply chain nodes (Figure 9). The degrees of risk/vulnerability of supply chain nodes were identified.

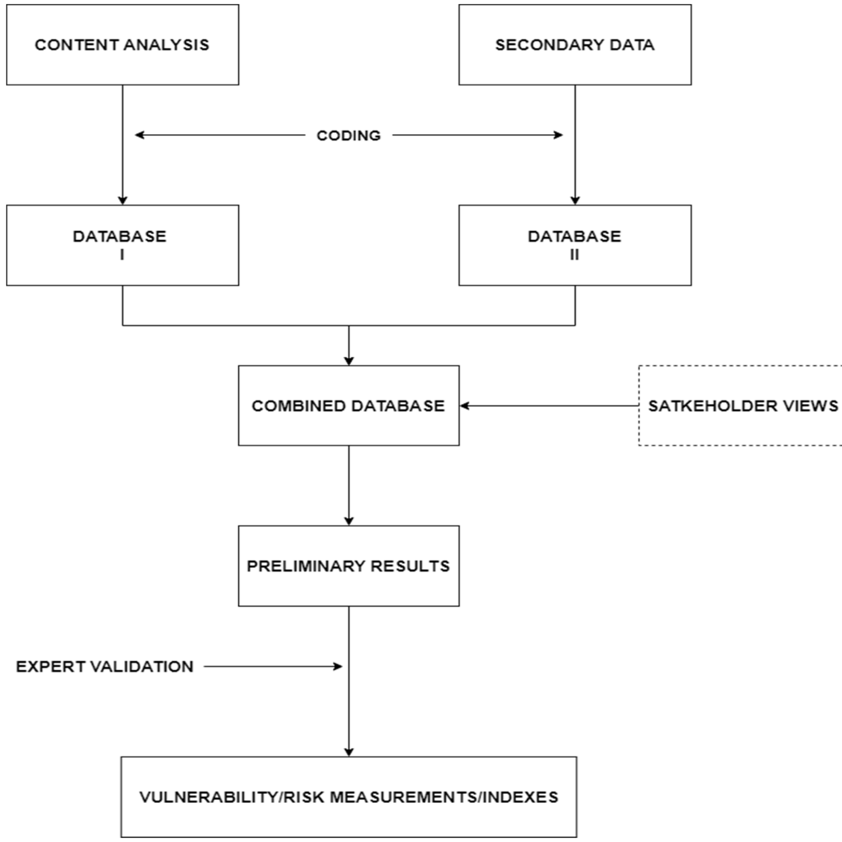


Figure 9. Data processing and analysis

CHAPTER 4 FINDINGS

This chapter presents the findings under the supply chains of four commodities, the impact of Covid-19 on CRFS and governance.

4.1 IMPACT OF CLIMATE HAZARDS ON THE PADDY /RICE SUPPLY CHAIN

- Paddy producers are mainly affected by drought.
- Drop in paddy production due to climate hazards prompted import of rice.
- The short supply of paddy due to climate hazards affects the milling industry.
- Oligopolistic behaviour of intermediaries especially collectors and millers influences the farmers' share and market prices.
- The large rice millers with modern machinery and storage facilities add value to the rice supply chain and play a significant role in supplying rice to the Colombo CRFS.
- Climate impacts in the production regions translate into price hikes in the Colombo city region.
- Apart from the impact of climate hazard on price, price inflation and leakages as spoilage influence the retail price.
- Most vulnerable to climate hazards: consumers, producers and small-scale millers

4.1.1 Overview of paddy production

Rice is the most important crop occupying about 34% of the total cultivated area in Sri Lanka. Paddy is cultivated in all 25 districts in the country in two cropping seasons (Maha and Yala). The dry zone contributes to about 60% of annual rice production. Colombo District contributes less than 0.3% to national production. Annually about 5 million tonnes of rice are produced (Table 12) and Sri Lanka is self-sufficient in rice. However, due to climate hazards, at times, the country has imported rice to meet local requirements.

Table 12. National paddy production and extent from 2018 to 2019

Item	2018		2019	
	Maha	Yala	Maha	Yala
Extent sown (ha)	667,191	373,763	748,027	368,906
Production (tonnes)	2,396,926	1,532,905	3,072,581	1,519,475

Source: DCS (2021)

4.1.2 Identification of hazards

The three districts that were selected contributed 37% and 47% to national paddy production in Maha and Yala seasons respectively in 2019. Hence, it is reasonable to assume that variations in production in these three important districts are likely to affect rice supplies to the Colombo city region. The major climate hazard that has impacted these three districts is drought. As shown in Figures 10, 11, 15 and 16 drought events were reported from 2015 to 2020 in Ampara, Anuradhapura and Polonnaruwa respectively. In addition, other climate hazards such as heavy rain and flood events were reported. However, the impact of these heavy rain and flood events on paddy production was negligible.

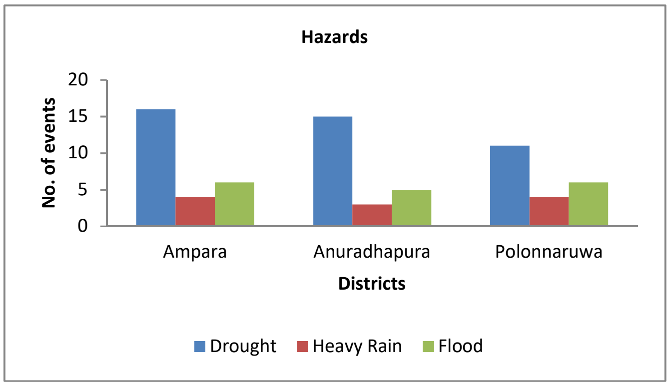


Figure 10. Frequency of hazard events in the production regions
Source: Content analysis.

The highest hazard score was reported in 2017 with clear implications for paddy production in that year (Figure 11). In all three districts, Maha and Yala production in 2017 was below the long-term average production of the respective seasons. Concomitantly, national paddy production followed the same pattern. This prompted the import of a significant quantity of rice to meet the shortfall in the local rice supply (Figure 22).

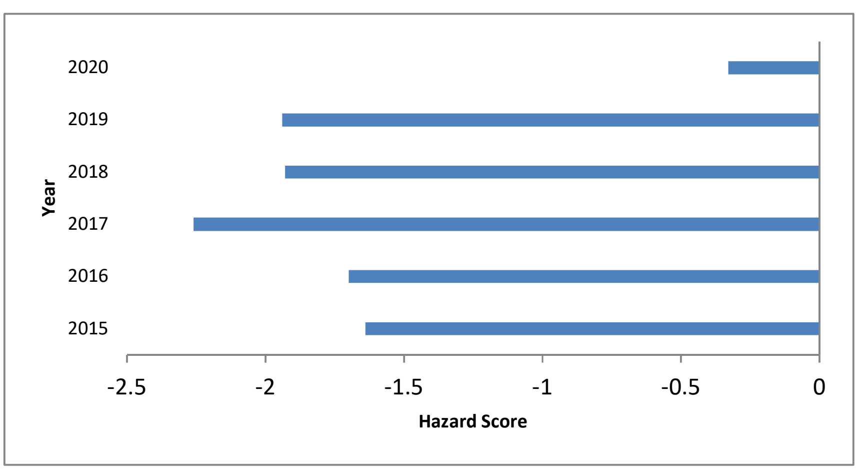


Figure 11. Hazard scores for the production regions from 2015 to 2020

Source: Authors.

The relative intensity of hazards is not significantly different among the three districts as most hazard events can be categorized as strong (Table 13).

Table 13. Intensity of hazards by production regions

Location	Severe	Very strong	Strong	Moderate	No impact	Total
Ampara	2 (9%)	0	18 (78%)	2 (9%)	1 (4%)	23
Anuradhapura	2 (9%)	0	15 (68%)	3 (14%)	2 (9%)	22
Polonnaruwa	2 (11%)	0	11 (58%)	4 (21%)	2 (11%)	19

Note: Severe = loss of life plus other damages; very strong = loss of life; strong = injury or other health impacts; moderate = loss of property.

Source: Authors.

4.1.3 Risk and vulnerability of rice supply chains

The content analysis results shown in Tables 14 and 15 indicate that the vulnerability and risk scores in absolute terms in all three districts were moderate. Although hazard is not considered in the calculation of vulnerability, an intense hazard event can inflict more damage when the subjects are more sensitive to the hazard, therefore, they are likely to become more vulnerable.

Table 14. Intensity of vulnerability by paddy production regions

Location	Highly vulnerable	Moderately vulnerable	Less vulnerable	Total
Ampara	0	21 (91%)	2 (9%)	23
Anuradhapura	0	19 (86%)	3 (14%)	22
Polonnaruwa	0	17 (89%)	2 (11%)	19

Source: Authors.

Table 15. Intensity of risk by paddy production regions

District	High risk	Moderate risk	Low risk	Total
Ampara	2 (9%)	19 (82%)	2 (9%)	23
Anuradhapura	3 (14%)	16 (72%)	3 (14%)	22
Polonnaruwa	1(4%)	16 (84%)	2 (11%)	19

Source: Authors

The ranking of vulnerability and risk scores of the three major paddy-producing districts (Figure 12) confirms the vulnerability ranking estimates of the Ministry of Environment as illustrated in Figure 13 (AgStat, 2019). Anuradhapura is more vulnerable and carries higher risk among the three main paddy-producing districts in Sri Lanka. This may be attributable to the fact that Anuradhapura District has comparatively higher proportion of paddy lands that depend on minor irrigation (Figure 14).

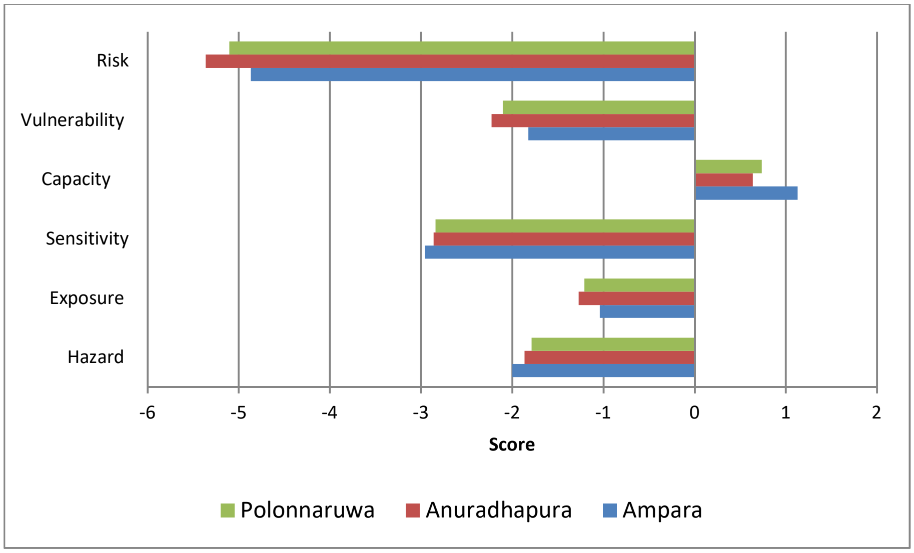


Figure 12. Scores related to risk and vulnerability by paddy production regions

Source: Authors.

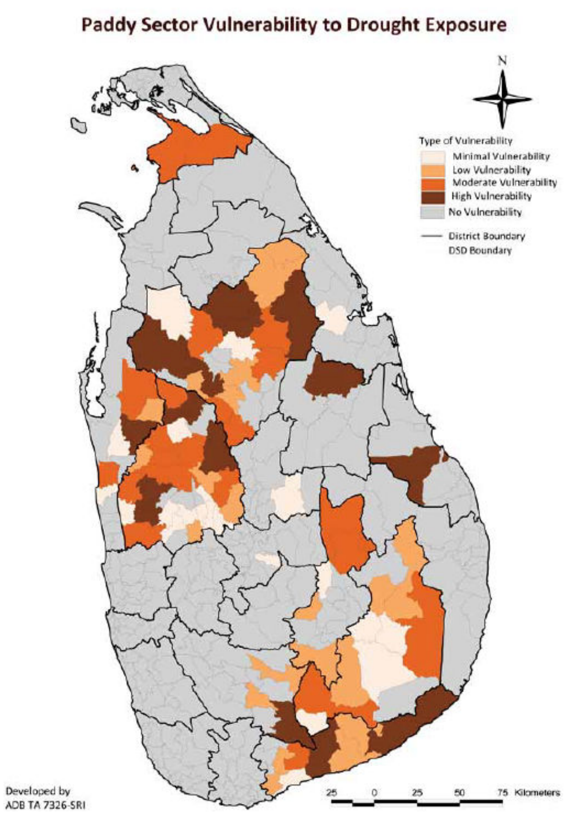


Figure 13. Vulnerability of paddy production regions to drought

Source: Ministry of Environment (2011).

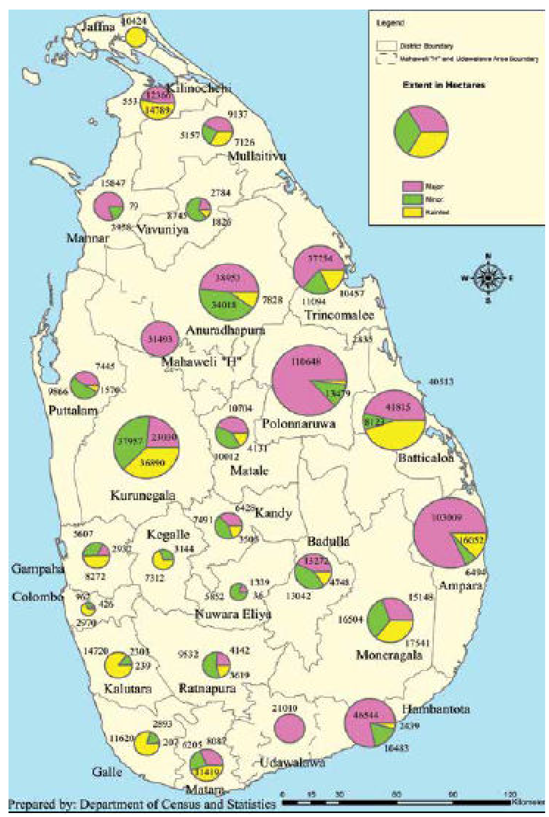


Figure 14. District-wise source of irrigation for paddy cultivation

Source: AgStat (2019).

4.1.4 Impact of climate hazards on paddy production

National paddy production in 2017 was the lowest production reported in the recent decade (Figure 21). The rainfall from both southwest and northeast monsoons was relatively low leaving inadequate water for filling the reservoirs. The rainfall during October, November and December in 2016 was below the seasonal average and as result not enough water was available to fill the major irrigation tanks as well as minor irrigation tanks. A significant extent of land in Anuradhapura is irrigated from minor irrigation tanks. In addition, these low rainfall months coincided with the 2016/2017 Maha paddy growing stage (Figures 15 and 16). As a result, paddy production in Anuradhapura District dropped by 78% compared to the average Maha yield in the district. The 2017 Yala production also dropped by 76% compared to the average; this can be mainly attributed to low rainfall in the months of April, May and June 2017. A production drop of 49% resulted in the 2017/2018 Maha due to poor rainfall in December 2017.

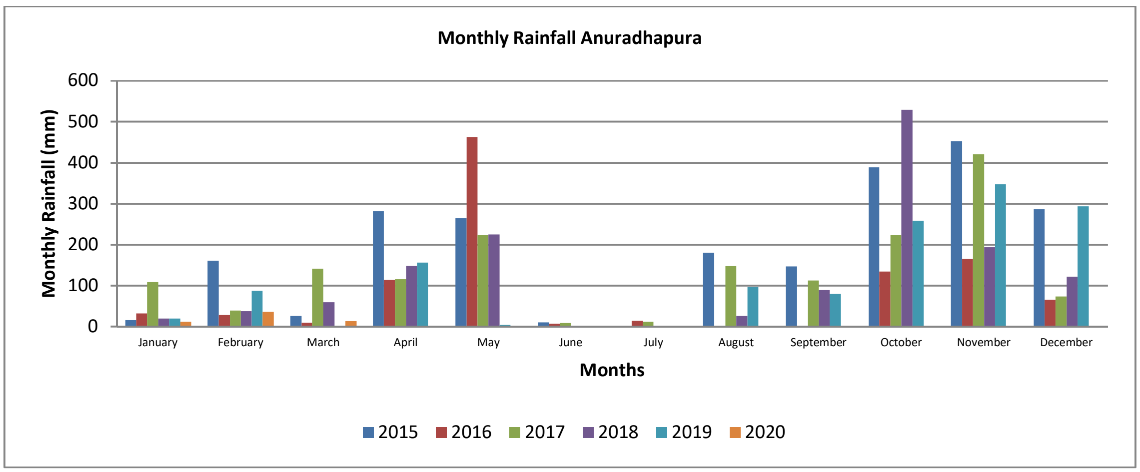


Figure 15. Monthly rainfall in Anuradhapura District from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.

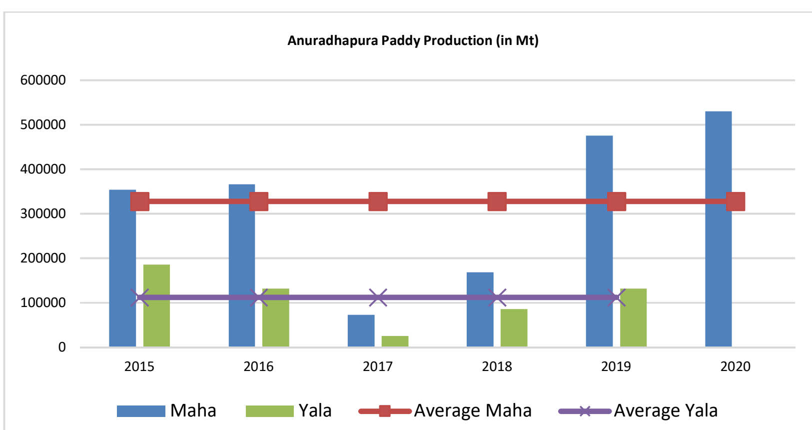


Figure 16. Paddy production from the 2014/2015 Maha to the 2019/2020 Maha in Anuradhapura

Note: The given year in the horizontal axis covers the Maha season from the previous year.

Source: Compiled from databases of Department of Census and Statistics, Sri Lanka.

In Polonnaruwa District, the rainfall in October and December 2016 was relatively low, as a result 2016/2017 Maha production declined by 26%. The low rainfall received in April and May 2017 can be attributed to the drop of production by 31% in the 2017 Yala season. The 2018/2019 Maha production is almost equal to the average production, that could be due to good rainfall in October and November in the previous year which contributed to fill-up minor and major irrigation tanks (Figure 17 and Figure 18).

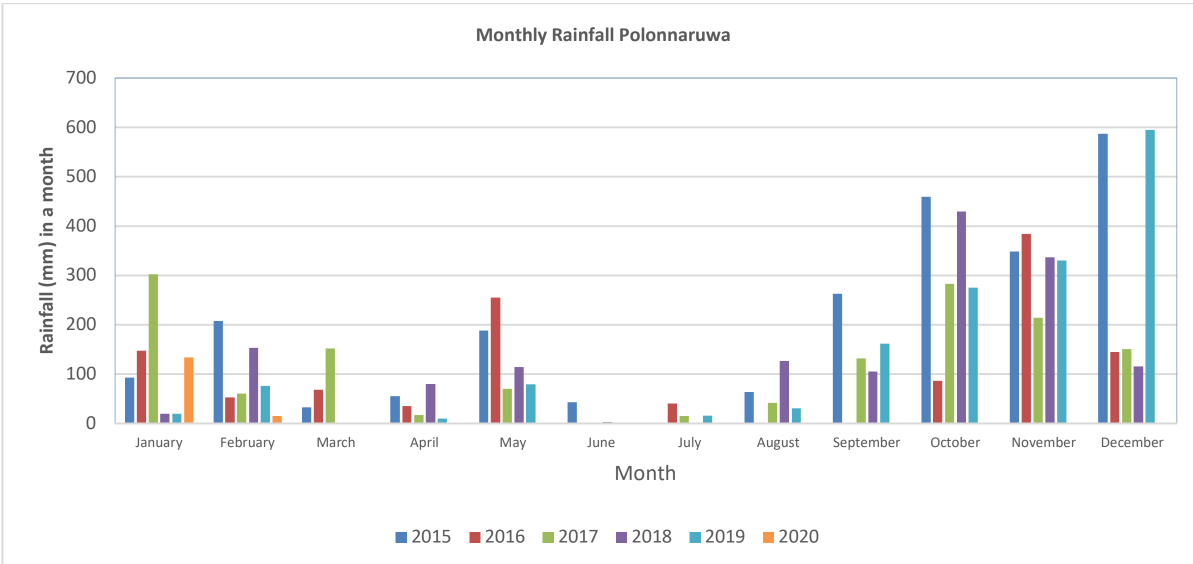


Figure 17. Monthly rainfall in Polonnaruwa District from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.

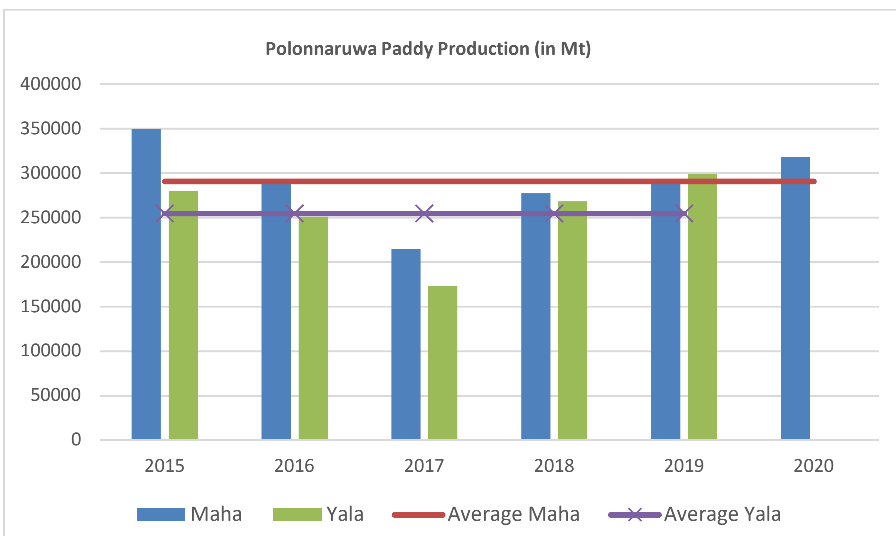


Figure 18. Paddy production from the 2014/2015 Maha to the 2019/2020 Maha in Polonnaruwa

Note: The given year in the horizontal axis covers the Maha season from the previous year.

Source: Compiled from databases of Department of Census and Statistics, Sri Lanka.

In Ampara District, there was no significant drop in production in the 2016/2017 Maha. However, production dropped in the 2017 and 2018 Yala due to relatively low rainfall received during April and May 2017 and 2018 (Figure 19 and Figure 20).

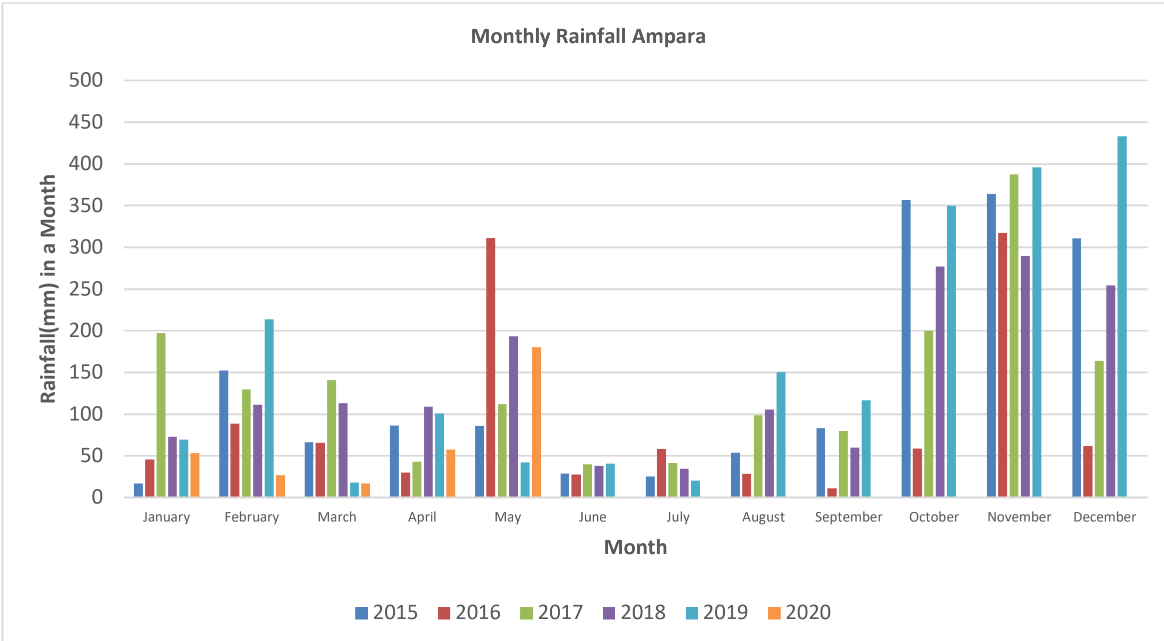


Figure 19. Monthly rainfall in Ampara District from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.

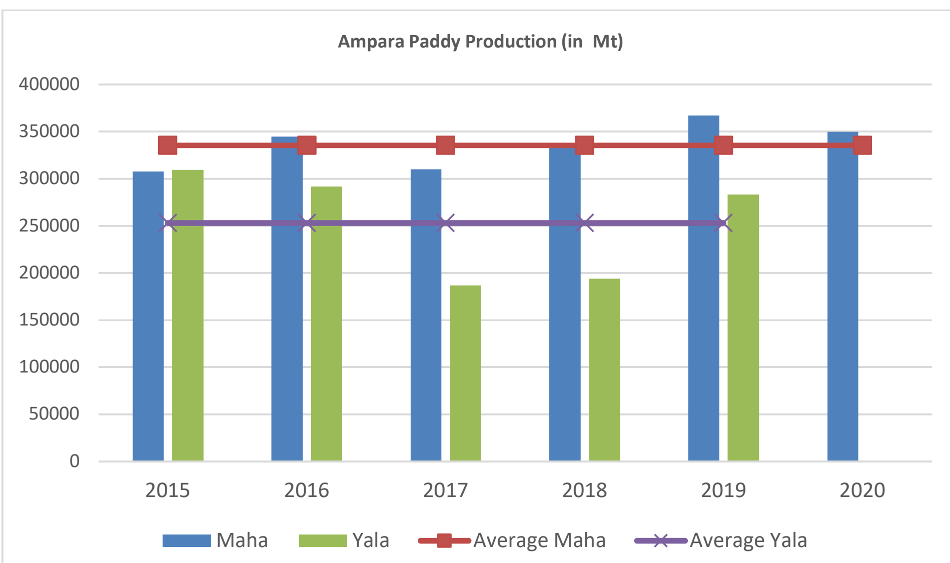


Figure 20. Paddy production from the 2014/2015 Maha to the 2019/2020 Maha in Polonnaruwa

Note: The given year in the horizontal axis covers the Maha season from the previous year.

Source: Compiled from databases of Department of Census and Statistics, Sri Lanka.

National paddy production declined in both the 2016/2017 Maha season and the 2017 Yala season by 49.2% and 40.1%, to 1.47 million tonnes and 0.91 million tonnes, respectively (Figure 21). The northeast monsoon that usually fills up the dry zone tanks towards the last quarter of the year also failed, leading to low water levels to grow rice in 2016/2017. Further, the southwest monsoon in 2017 did not bring sufficient rain for water to be stored for agricultural purposes for the 2017 Yala season.

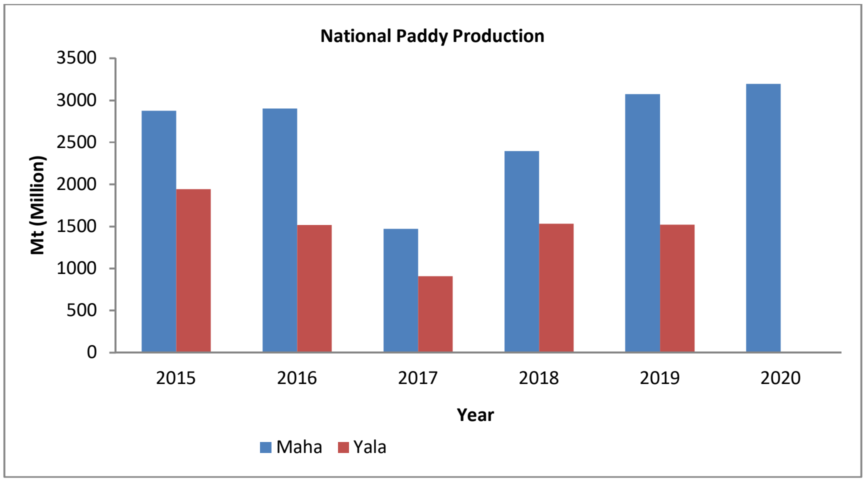


Figure 21. National paddy production from the 2014/2015 Maha to the 2019/2020 Maha

Note: The given year in the horizontal axis covers the Maha season from the previous year.

Source: Compiled from databases of Department of Census and Statistics, Sri Lanka.

The poor paddy production in the 2016/2017 Maha and 2017 Yala seasons created a shortfall in rice for local consumption which was mainly attributed to climatic factors. This necessitated the import of 750,000 tonnes of rice. In good years of production, imports remain relatively low as illustrated in Figure 22.

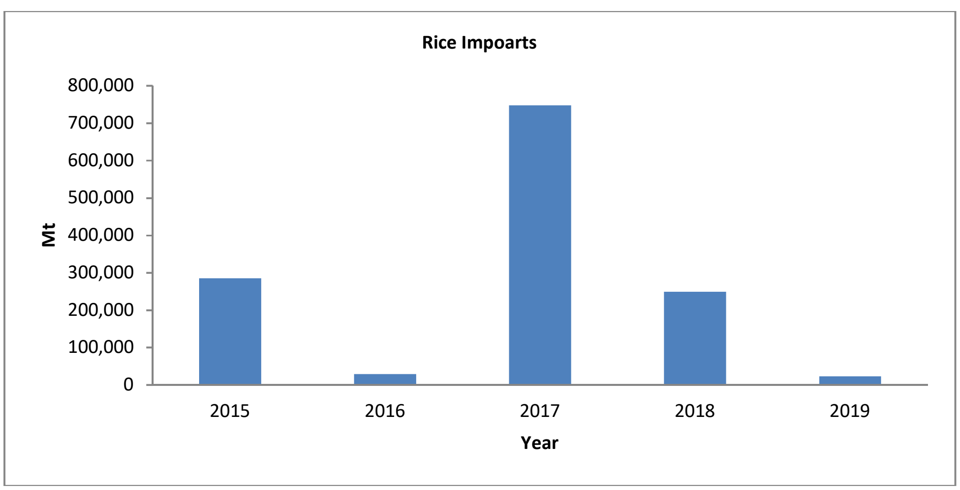


Figure 22. Rice imports from 2015 to 2019

Source: Compiled from Economic and Social Statistics of Sri Lanka, CBSL (2020).

Temperature is another important climatic parameter likely to impact rice production. Examination of maximum temperatures in the major production districts over the last five years revealed that temperature has already reached threshold levels at critical growth stages of the paddy plant. However, there is no evidence that the temperature has contributed to yield reduction. This result is in line with the findings of Weerakoon & Costa (2009). However, a slight increase in temperature in the future will have a negative impact on national rice production.

4.1.5 Impact of climate hazards on storage and processing of paddy/ rice

Paddy storage and milling operations are mainly in the hands of the private sector. The Paddy Marketing Board (PMB) owns 213 warehouses with a capacity of 242,000 tonnes (PMB, 2014). Of these storage facilities, many are in poor condition (Senanayake & Premaratne, 2016). The PMB only purchases a limited amount of annual production as shown in Table 16. In 2015, the PMB purchased about 6.7% of the annual paddy production which was the highest amount reported at that juncture.

Table 16. Paddy purchase by the Paddy Marketing Board

Season	**Quantity of paddy purchased (tonnes)**				
	2011	2012	2013	2014	2015
Maha	3,470	115,786	138,650	4,576	148,369
Yala	75,172	10,476	94,376	-	175,266
Total	78,642	126,262	233,026	4,576	323,635

Source: PMB annual report (2015).

There are more than 7,000 rice mills in the country (Wijesooriya & Priyadarshana, 2013). Most are small-scale village-level traditional mills. These mills can be categorized, based on the type of machinery used, into three classes: modern, semi-modern and traditional. Both storage and milling are done in commercial mills. Large mills process about 33% of paddy while small- and medium-size mills process about 60% of the paddy output (Sri Lanka Co-operatives, 2019). Modern machinery for integrated operations including loading, cleaning, sorting and packaging, and storage facilities are available at large-scale mills. This helps to maintain the quality of rice supplied, especially to the high-end market in the Colombo city region. However, this value addition has a cost and it is reflected in the price. A few large millers are known to be controlling the rice market in Sri Lanka as often reported in the local media (Wijesooriya & Priyadarshana, 2013). The short supply of paddy due to climate hazards affects the milling industry. When the paddy supply drops there are instances where 50% to 60% of medium- and small-scale millers do not have adequate supplies to continue their operations (USDA, 2019).

4.1.6 Impact of climate hazards on rice prices

The climate impact on paddy production is directly reflected in the Colombo retail price of long grain rice. As shown in Figure 23, the price hike corresponds with the low national production in both the Maha and Yala seasons of 2017. Although a substantial quantity of rice was imported to compensate for the shortfall, prices did not decline to ease the burden on the consumer. The possible reason could be the time lag of the imported rice reaching the market. This has implications for paddy cultivation in the following season as well as farmers because rice prices in the subsequent season have dropped. This clearly shows failure by policy-makers to make proactive decisions and maintain a buffer stock to absorb climate shocks which has become the norm in the recent years. It is not clear whether the government maintains a buffer stock of rice; no official statistics on buffer stocks are available. According to media reports, the government periodically imports rice to maintain a buffer stock. In 2018, it was reported that 100,000 tonnes of rice were imported for maintaining a buffer stock ("Sri Lanka to import", 2020).

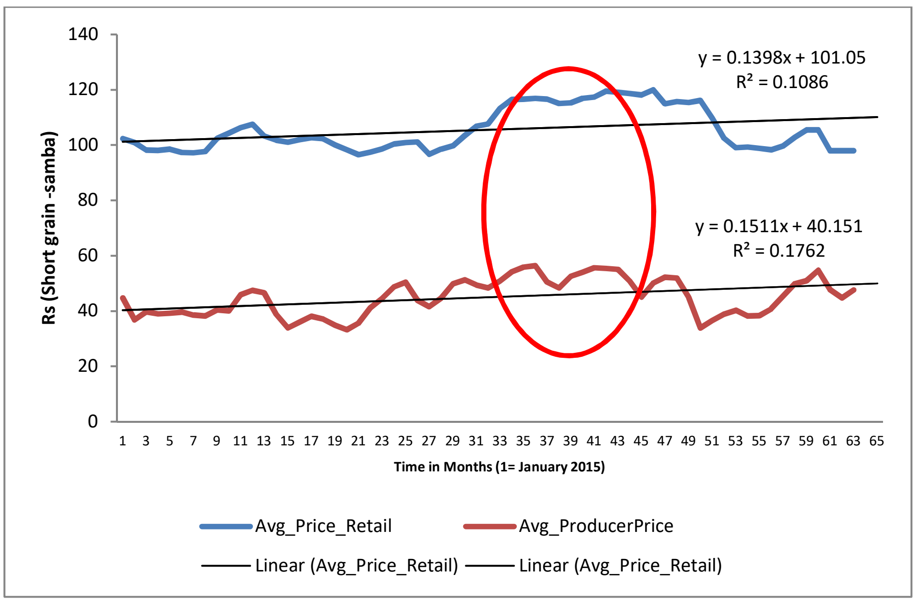


Figure 23. Price fluctuations of rice (short-grain samba) in the Colombo city region

Source: HARTI, Monthly Food Commodities Bulletin, various months.

According to Figure 24, it is evident that the increasing price trend is mainly due to price inflation as the real price remains relatively stable over the years, except during the periods of climate extremes mainly due to drought in the production regions. The oligopolistic behaviour of some large-scale millers contributes to price fluctuations in the off seasons (Kuruppu, 2017). Use of rice for value-added industries such as beer production also contributes to price increases (" Complain about", 2021). There are a significant number of reports of confiscating spoiled rice stocks in the media (Appendix I). The reasons for spoilage could be climate-related factors, poor storage or other factors. Malpractices could also contribute to price volatility.

Figure 24. Retail white rice real and nominal prices from July 2006 to November 2020

Source: FAO GIEWS (2020).

4.1.7 Possible implications of climate hazards on the rice supply chain, food security and nutrition

Although Sri Lanka has been self-sufficient in rice during severe climate hazards (e.g. in both cultivation seasons in 2017), the country has had to import a significant amount of rice to meet domestic rice demand. Per capita annual rice consumption in Sri Lanka is about 107 kg (Galappattige, 2020). However, a dietary estimate revealed that an average Sri Lankan consumes about 114.7 kg of rice and rice-based foods (Jayatissa et al., 2014). The estimated annual per capita rice consumption for Colombo District is approximately 81 kg (based on Household Income and Expenditure Survey [HIES], 2016). The disparity in per capita consumption could be attributed to the food habits and preferences of the inhabitants in the Colombo city region. There is evidence of a shift from cereal-based food to more vegetable, meat and fish-based diets (FAO, 2016). However, this may not be applicable for poorer segments of the population in the Colombo city region. Studies based on per capita food energy intake indicate that Colombo District is the most food insecure district in the country (Mayadunne & Romeshun, 2013). Since food prices influence the calorie availability of households (Nirmali & Edirisinghe, 2010), frequent price fluctuations can impact rice consumption and thus food energy intake of the poorer segments in the Colombo city region. Rice provides about 42% of total calorie intake and one-third of protein intake (20 g out of 60 g per capita requirement) (MoHNIM, 2017).

It is projected that climate change will lead to an escalation of market prices of rice over the period leading up to 2040 (Cai et al., 2015). This will have serious implications for the affordability of rice among the poorer segments of society and thus on dietary energy intake. Further, the price escalation could have negative implications for food consumption choice and demand due to the complementary nature of rice and vegetables (Pallegedara, 2019). This could lead to reduction in consumption of vegetables when rice prices increase.

Figure 25 explains the pathway of climate hazards on food security and nutrition in the Colombo city region. Climate hazards, in particular drought, are having a serious impact on paddy production. The impact could be serious enough to threaten national self-sufficiency as happened in 2017. Climate hazards have implications on intermediary nodes of the rice supply chain in terms of lack of volume for milling and storage. Climate hazards in the production regions are clearly reflected in the Colombo retail price of rice. The high price fluctuation will have implications for affordability and dietary energy intake of the poorer segments in the Colombo city region as it has the most food insecure population in the country.

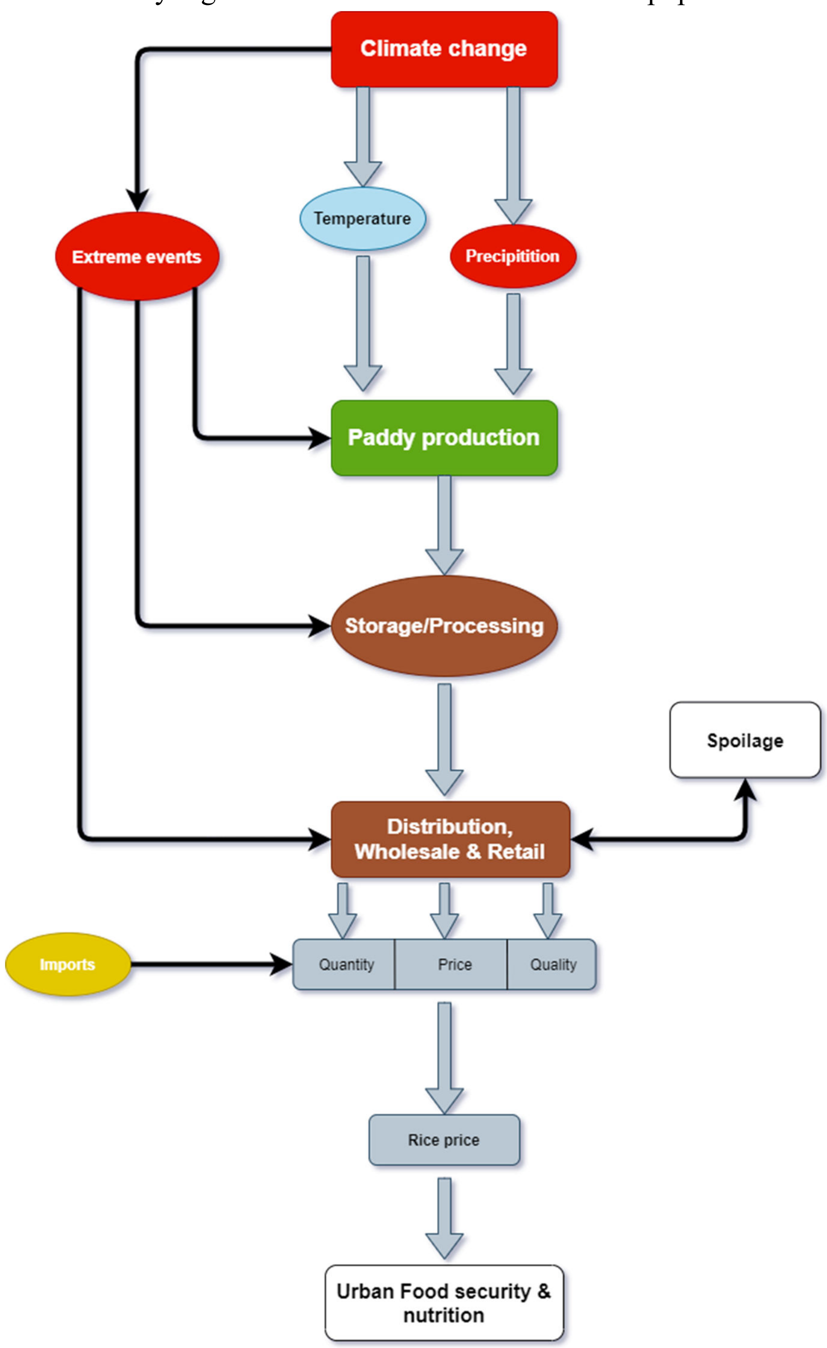


Figure 25. Cascading effects of climate hazards on food security and nutrition in the Colombo city region

Source: Authors.

4.2 IMPACT OF CLIMATE HAZARDS ON UPCOUNTRY AND LOW COUNTRY VEGETABLE SUPPLY CHAINS

- The major climate hazards affecting the upcountry vegetable production regions are wind, landslides, flooding and heavy rains while the major low country vegetable-producing district, Anuradhapura is affected by drought.
- The upcountry and low country vegetable supply chain intermediaries are also affected by climate hazards. At the intermediary nodes, heavy rain and wind have been the main hazards affecting operations of upcountry DECs.
- The impact of climate hazards on production regions carries over along the supply chain to the consumer in terms of price hikes.
- The DEC-based traditional vegetable supply chains are responsible for about 85% of vegetable supplies to the Colombo city region.
- DECs lack basic infrastructure such as cold chain facilities, storage space, other basic amenities and technical and management expertise for smooth operation.
- Supermarket supply chains are more efficient and have demonstrated the value of private sector intervention.
- Farmers operating in vegetable supply chains connected directly with supermarkets via the supermarket network of collection centres can contribute to shortening the supply chain.
- Heavy and erratic rainfall has prompted upcountry vegetable farmers to use excessive amounts of agrochemicals such as fungicides and pesticides with possible agrochemical contaminants in the vegetables reaching Colombo.
- The impacts of climate hazards on production and excessive postharvest losses along the supply chain are the main reasons for unaffordability of vegetables among the poorer segments of the population.

4.2.1 Overview of upcountry vegetables

Nuwara Eliya and Badulla districts predominantly produce all the upcountry vegetable types. In 2019, Nuwara Eliya District contributed 57%, 75%, 86% and 37% of cabbage, carrot, leeks and beans respectively while Badulla District contributed 22%, 23%, 10% and 35% of the same vegetables to national production (DCS, 2020a) (Appendix II). The contribution from Colombo District to national production is negligible. Therefore, most upcountry vegetable types are supplied to the Colombo city region from these two districts with significantly high food miles.

4.2.2 Overview of low country vegetables

Unlike upcountry vegetable production, low country vegetable production is scattered throughout the country. Among many districts, Anuradhapura District is responsible for about 25% of low country vegetable production in the country. Other districts making a significant contribution to national production include Moneragala and Hambantotta (Appendix III). The contribution from Colombo District to national production is about 1.2%. Therefore, supplies to Colombo originate mainly from DECs located closed to production regions such as Dambulla, Tambuttegama and Embilipitiya.

4.2.3 Identification of climate hazards for production of upcountry and low country vegetables

The major climate hazards affecting Nuwara Eliya and Badulla districts are wind, landslides, floods and heavy rain. From 2015 to 2020, out of 50 climate hazard events, 30 wind, 22 landslide, 22 flood and 8 heavy rainfall events have been reported in Nuwara Eliya District. In Badulla District, wind is the predominant climate hazard, while heavy rain and floods have also affected upcountry vegetable production. The major climatic hazard experienced by Anuradhapura District is drought. The district mainly receives rainfall from the northeastern monsoon from October to January; this period overlaps with the major Maha cultivation season, which is responsible for 60% of low country vegetable production. Climate hazards such as heavy rain, floods, landslides and wind events in the districts of Ratnapura, Kandy and Kegalle located along the transport routes have affected transportation of vegetables from Nuwaraeliya and Badulla districts to Colombo city region (Table 17).

Table 17. Climate hazard events reported in production regions and along transport routes

District/no. of events	Heavy rain	Floods	Landslides	Wind	Drought
Nuwara Eliya (50 events)	8 (16.0%)	22 (44.0%)	22 (44.0%)	30 (60.0%)	2 (4.0%)
Badulla (36 events)	8 (22.2%)	7 (19.4%)	8 (22.2%)	25 (69.4%)	5 (13.9%)
Anuradhapura (22 events)	3 (13.6%)	5 (22.7%)	0	0	15 (68.2%)
Ratnapura (21 events)	15(71.4%)	7 (33.3%)	8 (38.1%)	4 (19%)	4 (19%)
Kandy (6 events)	4 (66.7%)	3 (50%)	3 (50%)	2 (33.3%)	1 (16.7%)
Kegalle (10 events)	8 (80%)	5 (50%)	6 (60%)	3 (30%)	0

Note: Percentages and number of hazard events are not mutually exclusive.

Source: Authors.

According to Table 18, the hazard intensities in Nuwara Eliya and Badulla are moderate as wind is the most prevalent hazard. Only 14% and 18% of the hazard events were severe for the districts of Badulla and Nuwara Eliya respectively. Nuwara Eliya District has reported more climate hazards compared to Badulla District. The hazard events in Anuradhapura are strong in intensity as drought is the prevalent hazard. Although, the hazard intensity in Kegalle is relatively severe it has minimum impact on the transport of vegetables from the upcountry region. The Colombo–Badulla road used to transport vegetables from upcountry is often impacted by floods and landslides in Ratnapura District as around 24% of the hazard events in the district are severe in intensity.

Table 18. Intensity of hazards by production regions and along transport routes

Location	Hazard category					Total
	Severe	Very strong	Strong	Moderate	No impact	
Nuwara Eliya	9	0	2	36	3	50
	18.0%	0%	4.0%	72.0%	6.0%	
Badulla	5	0	4	25	2	36
	13.9%	.0%	11.1%	69.4%	5.6%	
Anuradhapura	2	0	15	3	2	22
	9%	0	68.2%	13.6%	9%	
Kandy	1	1	1	3	0	6
	16.7%	16.7%	16.7%	50.0%	0%	
Kegalle	6	1	0	2	1	10
	60.0%	10.0%	0%	20.0%	10.0%	
Rathnapura	5	2	2	6	6	21
	23.8%	9.5%	9.5%	28.6%	28.6%	

Note: Severe: loss of life plus other damages; very strong: loss of life; strong: injury or other health issues; moderate: loss of property.

Source: Authors.

4.2.4 Risk and vulnerability of vegetable supply chains

The high vulnerability in Nuwara Eliya and Badulla districts is due to wind events seriously affecting vegetable production (Table 19). This was confirmed by Kumara et al. (2015) who reported that polytunnels and vegetable crops are damaged by heavy wind. The vulnerability scores which are independent from hazard scores indicate that vulnerability of the production areas of Nuwara Eliya and Badulla is high which implies that these regions are sensitive and lack capacity to withstand climate hazards. In line with the vulnerability, the risk score is also high for the two districts (Figure 26). This is also confirmed by the high risky nature of the climate hazards in the two districts (Table 20).

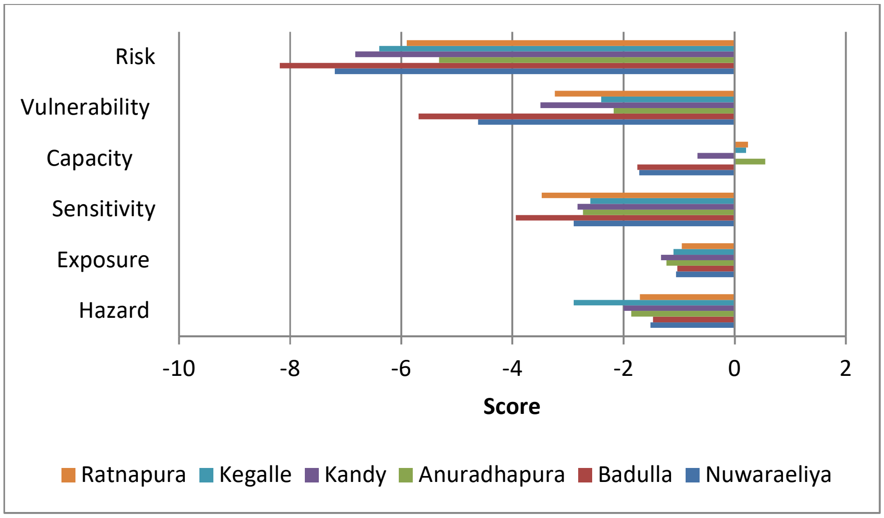


Figure 26. Scores related to risk and vulnerability by production regions and along transport routes. The implications are that production, collection and transport of upcountry vegetables are affected by the most prevalent climate hazards such as wind and heavy rain.

Source: Authors.

In Anuradhapura District, vulnerability is moderate and risk intensity is low. This can be attributed to relatively higher capacity due to the availability of water for cultivation of low country vegetables as about 60% of production occurs in the Maha season (DCS, 2020a). In August 2018 there was a severe drought in Anuradhapura District affecting more than 15,000 families. However, it did not affect Yala vegetable production probably because of alternative sources of water, such as groundwater, available for cultivation. It was reported that in minor irrigation schemes in Anuradhapura there are more than 10,000 dug wells or 27 wells per 100 ha (Kikuchi et al., 2003). The resilience of Anuradhapura District is further evidenced by reasonable climate change adaptation practices adopted by farmers such as irrigating vegetable cultivation by pumping water from agro-wells and canals. Most common climate change adaptation practices among vegetable farmers in Anuradhapura include changing planting times, crop rotation and irrigating vegetable fields as well as use of groundwater (Esham, 2021). In response to water scarcity in the dry zone, many farmers use groundwater from agro-wells to irrigate crops (Burchfield & Gilligan, 2016).

Table 19. Vulnerability by production regions and along transport routes

Location	**Vulnerability**			
	Highly vulnerable	Moderately vulnerable	Less vulnerable	Total
Nuwaraeliya	45	3	2	50
	90.0%	6.0%	4.0%	
Badulla	33	3	0	36
	91.7%	8.3%		
Anuradhapura	0	19	3	22
	0	86.4%	13.6%	
Kandy	3	3	0	6
	50.0%	50.0%		
Kegalle	2	6	2	10
	20.0%	60.0%	20.0%	
Rathnapura	7	14	0	21
	33.3%	66.7%		

Source: Authors.

The high-risk propensity of the upcountry vegetable supply chain implies that the impact of climate hazards, especially wind, can quickly transfer along the supply chain to the consumer in terms of significant price hikes. However, in low country vegetable supply chains, climate hazard impacts are not translated into retail price hikes at the same magnitude as in the case of upcountry vegetables. This can be attributed to the resilience of low country vegetable production to climate hazards due to the reasons discussed above.

Table 20. Risk by district in production regions and along transport routes

Location	**Risk**			
	High risk	Moderate risk	Low risk	**Total**
Nuwaraeliya	44	6	0	50
	88.0%	12.0%	0%	
Badulla	34	2	0	36
	94.4%	5.6%	.0%	
Anuradhapura	3	3	16	22
	13.6%	13.6%	72.7%	
Kandy	4	2	0	6
	66.7%	33.3%	.0%	
Kegalle	7	2	1	10
	70.0%	20.0%	10.0%	
Rathnapura	10	6	5	21
	47.6%	28.6%	23.8%	

Source: Authors.

4.2.5 Impact of climate hazards on upcountry vegetable production

Closer observation of production and climate data shows some relationship between rainfall and upcountry vegetable production. Of the Maha season production, the lowest yields were reported in 2019. The crops that contributed to this drop were tomatoes and leeks. Among the Yala seasons, 2015 was the year that reported the lowest production; all major upcountry vegetable crops contributed to the drop in production. Heavy wind and rainfall variation contributed to these production declines. In 2019, the drop in production could be attributed to low rainfall in November and December 2018. In 2015, relatively low rainfall in May and June which coincided with planting and high rainfall in September coinciding with the Yala season has contributed to the drop in production. Wind events have also heavily contributed to poor production, especially for beans and leeks (Figures 27, 28 and 29).

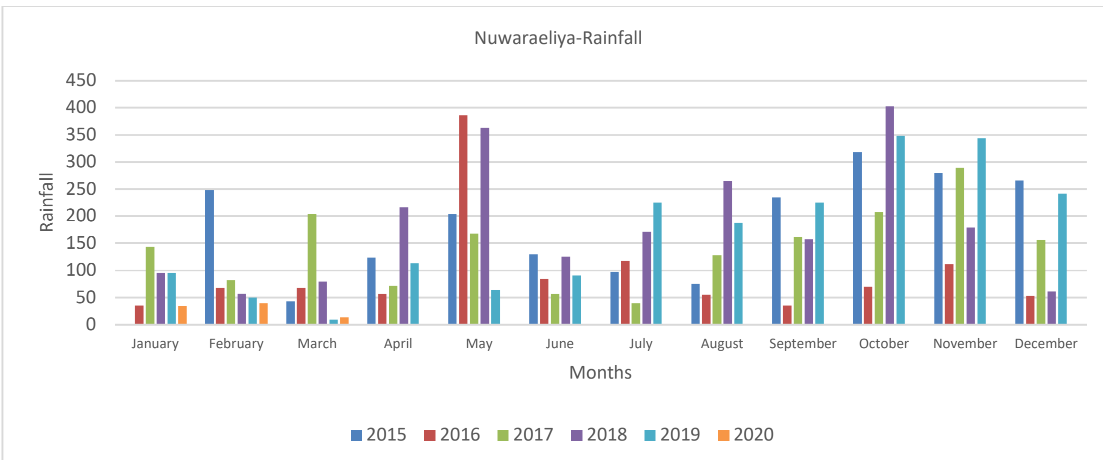


Figure 27. Monthly rainfall in Nuwara Eliya District from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.

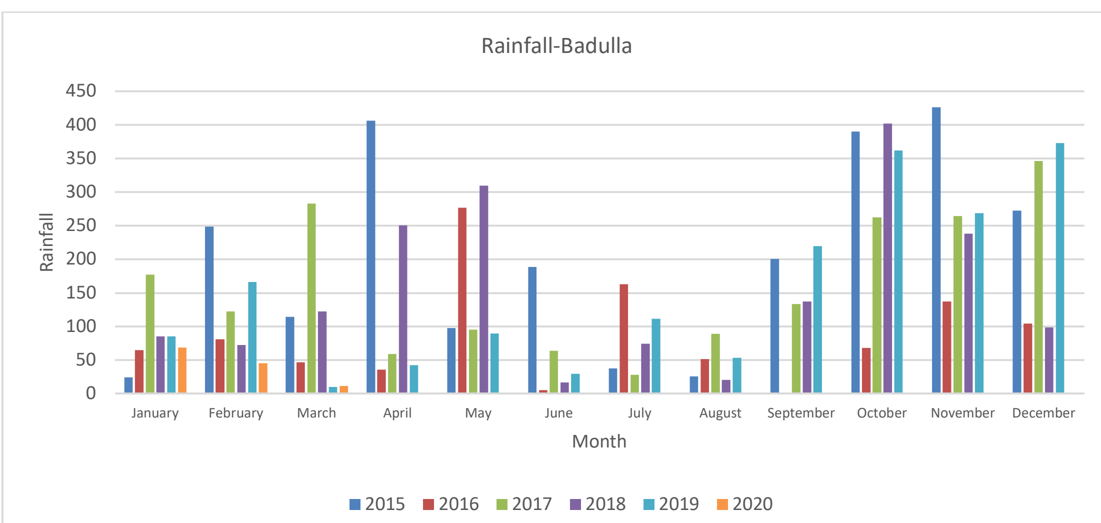


Figure 28. Monthly rainfall in Badulla District from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.

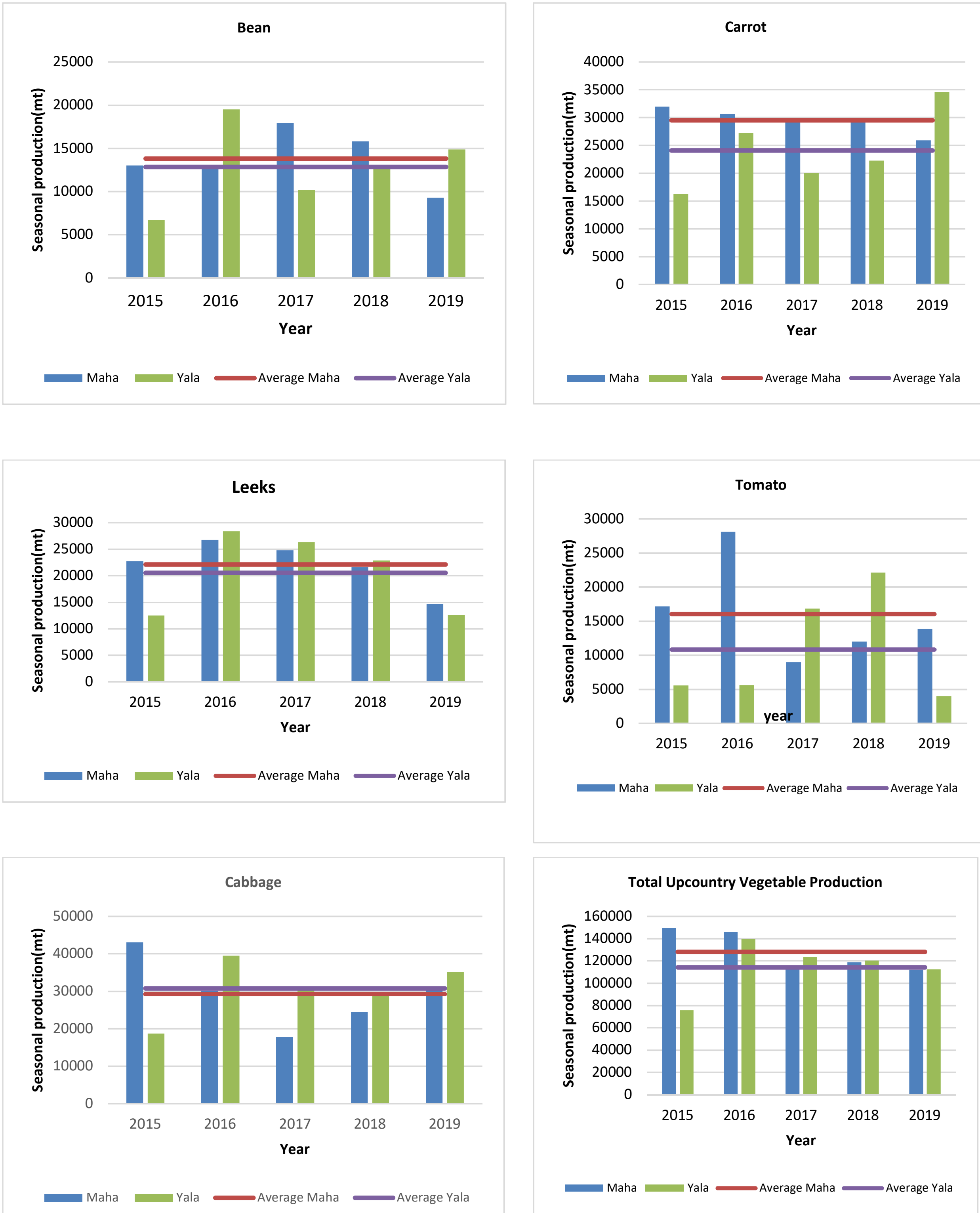


Figure 29. Seasonal upcountry vegetable production from 2015 to 2019

Source: Compiled from databases of Department of Census and Statistics, Sri Lanka.

4.2.6 Impact of climate hazards on low country vegetable production

Low country vegetable production in Anuradhapura was low and below average in the Maha season of 2017 owing to low rainfall towards the end of 2016. Of the Yala seasons, production was below average in 2015 and 2016. An erratic rainfall pattern with high rainfall at the beginning and end of the season damaged the 2015 Yala crops, consequently the major low country vegetable types cultivated in the district were affected. In 2016 high rainfall at the beginning of the Yala season impacted production of pumpkin, lady's finger and ash plantains (Figure 30 and Figure 31).

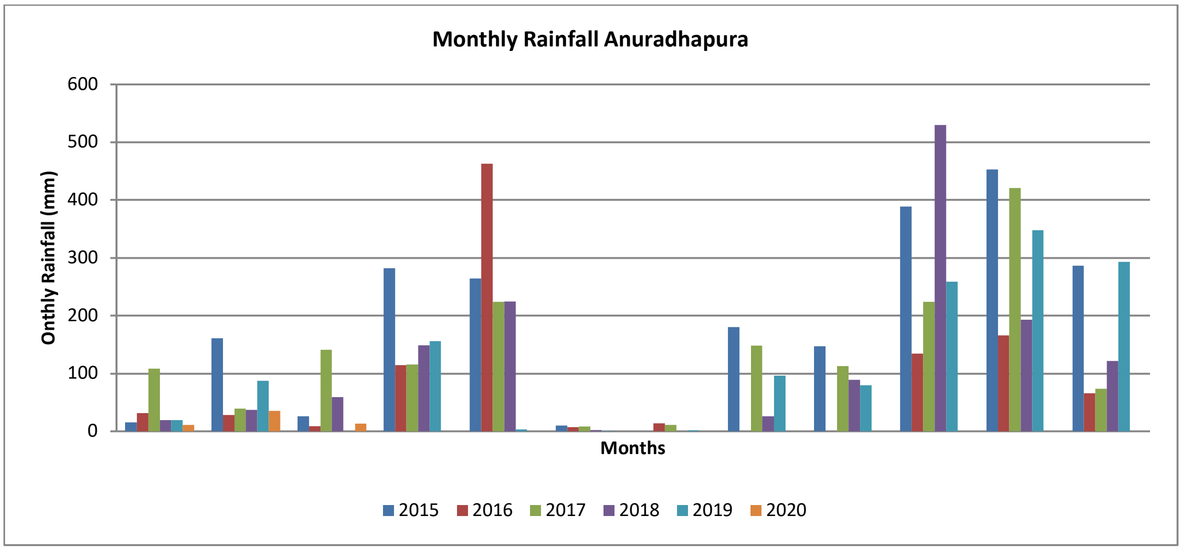
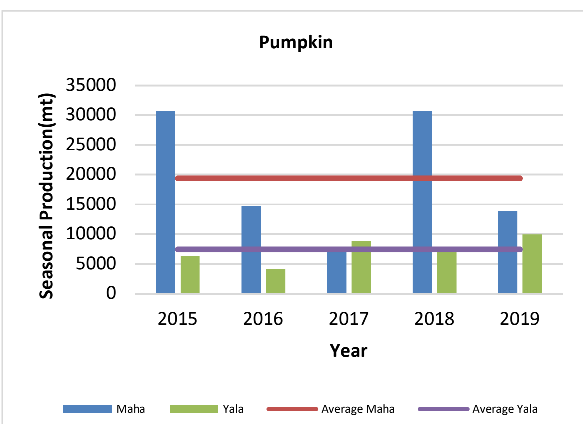
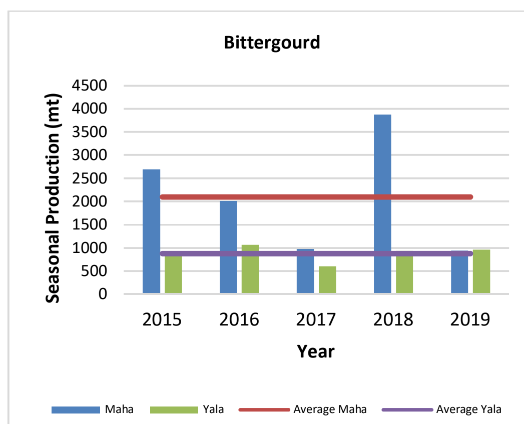


Figure 30. Monthly rainfall in Anuradhapura District from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.





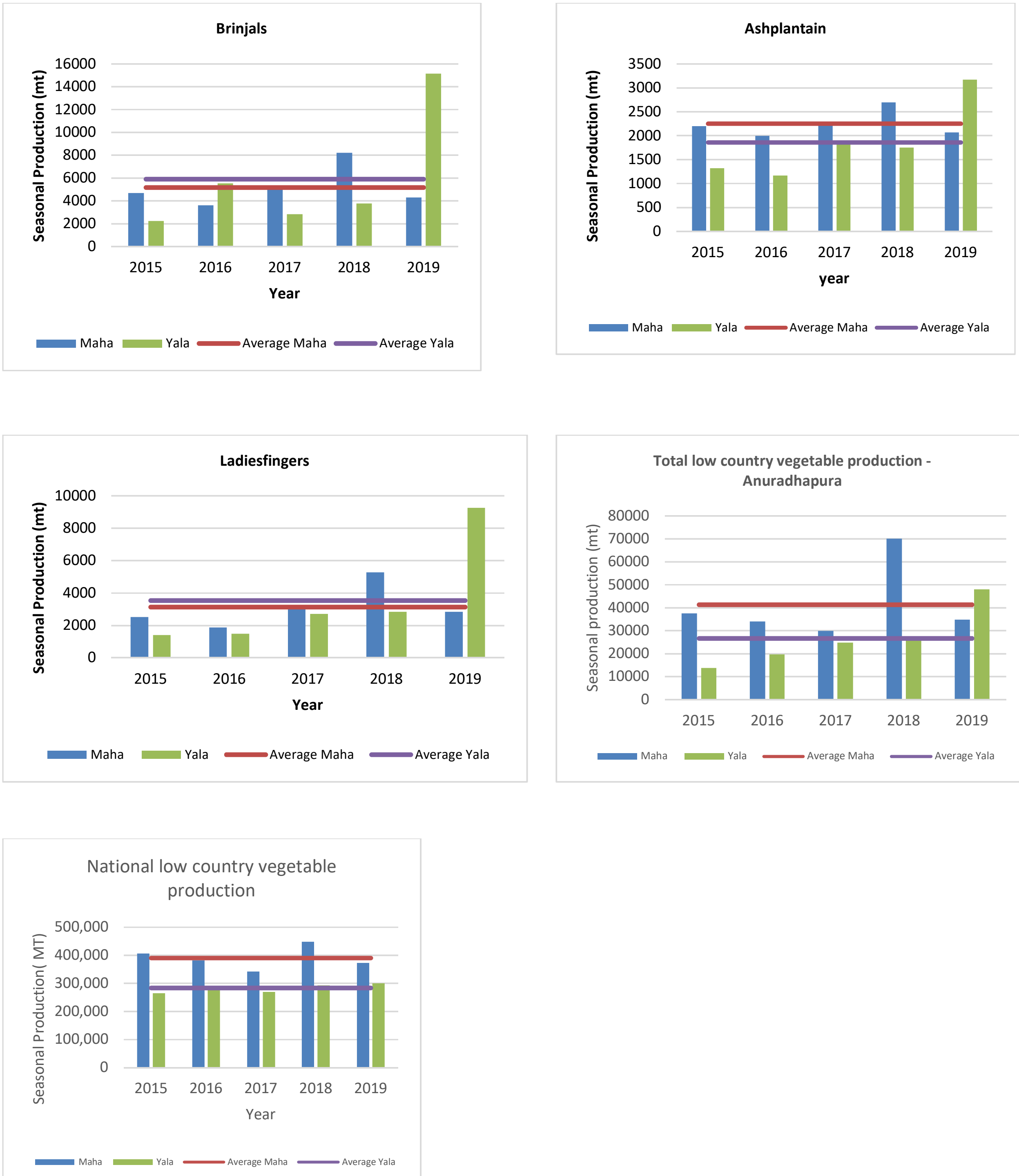


Figure 31. Seasonal low country total vegetable production and production in Anuradhapura District from 2015 to 2019

Source: Compiled from databases of Department of Census and Statistics, Sri Lanka.

According to Table 21, the overall hazard score was highly negative in 2017; corresponding with low national upcountry vegetable production in Maha 2017. However, the risk score remained comparatively low due to a number of reported relief measures put in place in 2017. Moreover, the hazard score was less negative in 2016 corresponding with high production in Maha 2016. These results show how climate hazards impact upcountry vegetable production. Unlike for upcountry vegetable production, a clear pattern cannot be recognized for low country vegetable production except for low production in Maha 2017, because production was scattered throughout the country as well as resilience in the low country vegetable production system as discussed earlier.

Table 21. Hazard, vulnerability and risk scores by year for major vegetable production districts

Year	Average score Std. Dev		
	Hazard score	Vulnerability score	Risk score
2015	-1.53	-5.29	-7.94
	1.23	0.47	1.30
2016	-1.39	-3.65	-5.87
	1.12	1.64	1.98
2017	-2.24	-3.44	-6.68
	1.79	2.66	3.45
2018	-1.80	-5.13	-7.93
	1.37	1.19	1.16
2019	-2.06	-4.06	-7.41
	1.39	1.52	1.74
2020	-1.00	-5.33	-7.33
	0.32	0.73	0.86
Overall	-1.71	-4.35	-7.12
	1.35	1.77	2.12

Source: Authors.

4.2.7 Impact of climate hazards on traditional supply channels of vegetables

The Manning Market is the central hub for vegetable distribution in Colombo city. It was relocated from Pettah to Peliyagoda in November 2020. The new Manning Market has 1,192 shops. These shops are operated by commission agents who purchase from collectors and farmers and resale to retailers and wholesalers. DECs play a significant role in distribution of vegetables within the Colombo city region. In total there are 14 DECs in the country out of which 5 (Narahenpita, Welisara, Meegoda, Piliyandala and Ratmalana) are located within the Colombo city region. In addition to these market facilities, there 18 other relatively large markets mainly involved in retailing of vegetables located within Colombo city limits in Maradana, Grandpass, Dematagoda, Borella, Wellawatta, Kirulapona and Narahenpita. There are other numerous vegetable retailers operating outlets including periodic markets known as *Pola.* In addition, mobile operators using trucks to deliver vegetables to consumers have become popular. The rough estimates indicates that traditional channels are responsible for supplying about 85% of the Colombo city region's vegetable requirements.

A survey was conducted with commission agents at DECs to understand the impact of climate hazards on upcountry and low country vegetable handling and postharvest losses. The survey covered 77 commission agents from Dambulla, Keppetipola, Nuwaraeliya, Embilipitiya and Meegoda (Table 22).

Table 22. Impact of climate hazards on operations of collectors and wholesalers based at DECs

DEC	No. of respondents	Heavy rain	Drought	Wind	High temperature
Dambulla	32	56%	44%	-	-
Keppetipola	24	67%	-	33%	-
Nuwara Eliya	02	100%	-	-	-
Meegoda	15	67%	33%	-	-
Embilipitiya	04		50%	-	50%

Source: Author's survey.

The survey results revealed that the climate hazards affecting DECs differ by location. Respondents from the upcountry DECs in Keppetipola and Nuwaraeliya stated that heavy rain and wind were the main hazards affecting their operations. In Dambulla, Meegoda and Embilipitiya rain, drought and high temperature hinder operations (handling and wastage of vegetables).

According to commission agents at Dambulla DEC, the mostly affected upcountry vegetables during handling at times of high temperature are tomatoes, cabbage and radish; low country vegetables are mainly gourds. During handling, high rainfall affects most of the vegetable types. In Keppetipola DEC and Meegoda DEC, no vegetables are affected by high temperature. However, most upcountry vegetables are affected by heavy rainfall (Table 23).

Table 23. Wastage of vegetables at DECs due to climate hazards

Produce	Dambulla		Keppetipola		Meegoda	
	High temperature	Heavy rain	High temperature	Heavy rain	High temperature	High rain
Tomato	25.00%	38.33%	--	--	--	
Potato	--	25.00%	--	33.21%	--	20.00%
Carrot	--	23.33%	--	10.00%	--	20.00%
Leek	--	25.00%	--	20.00%	--	17.50%
Cabbage	25.00%	39.00%	--	41.00%	--	18.33%
Beans	--	46.88%	--	10.63%	--	15.00%
Ridged gourd	10.00%	22.50%	--	--	--	10.00%
Pumpkin	--	15.00%	--	--	--	
Chili	--	25.00%	--	--	--	10.00%
Radish	25.00%	25.00%	--	--	--	10.00%
Knolkhol	--		--	50.00%	--	--
Brinjal	--	35.00%	--	17.50%	--	--
Green onion	90.00%		--	--	--	--
Snake gourd	25.00%	12.50%	--	--	--	--

Bitter gourd	--	25.00%	--	--	--	--
Onion	--	--	--	--	--	10.00%

Source: Author's survey.

The climate hazards significantly affect the supply of certain vegetables. Supplies of tomatoes, potatoes, leeks and brinjal drop significantly at Keppetipola due to heavy rains while heavy wind impacts on supply of brinjals and beans. Tomatoes, pumpkin and cucumber supplies to Dambulla are affected by drought. Supplies to Dambulla and Keppetipola are not affected by floods (Table 24).

Table 24. Supply drop due to climate hazards

Location	Heavy rain	Drought	Floods	Wind
Dambulla		23% tomato 50% lady's finger 25% cucumber 30% pumpkin	No drop	
Keppetipola	33% tomato 49% potato 18% carrot 37% leek 29% beans 26% cabbage 30% brinjal		No drop	Beans 11% Potato 3% Brinjal 30%

Source: Author's survey.

According to respondents at DECs, climate is the major factor that influences vegetable prices followed by festival seasons and fuel prices. Interestingly, the cultivation season was not ranked as a significant factor as only 5% attributed seasonality to price fluctuation (Table 25). This could be due to year-round production of vegetables in the upcountry districts.

Table 25. Main factors affecting price according to wholesalers and retailers at DECs

Factor	No. of respondents	Percentage
Climate	48	58
Festival season	22	27
Fuel prices	8	10
Cultivation season	4	5
Fertilizer price	1	1

Source: Author's survey.

Early warning and climate forecasts are not considered seriously by the respondents at DECs. The major source of weather information for commission agents at DECs is TV and radio. Although all of them own mobile phones they are used rarely to access weather information (Table 26).

Table 26. Sources of weather/climate information

Information source	No. of respondents	Percentage

Mobile phone	6	10
TV/radio	45	74
Neighbours	5	8
Other	5	8

Source: Author's survey.

According to survey respondents, among the major challenges faced by commission agents that act as barriers to reducing wastage include lack of cold chain facilities, inadequate storage space, poor transportation of vegetables, practical difficulties in using plastic crates due to cost factors and delivery of low-quality vegetables by farmers to DECs. In order to minimize wastage and reduce food miles it is necessary to develop a decision support system to match the demand and supply of vegetables to the Colombo city region on a daily basis, possibly at major DECs with real-time connectivity.

4.2.8 Supermarket vegetable supply chains

Supermarkets play an important role as intermediaries in the supply of vegetables to the Colombo city region. The two leading supermarket chains, Keels and Cargills, collectively hold about 10% of the market share in supply of vegetables to Colombo city region (Table 29). Cargills has 411 outlets of which more than 300 are located in Colombo district. Vegetable collections take place at ten collection centres distributed across different agro-ecological zones. More than 95% of procurement is done through the collection centres which connect to about 10,000 outgrower farmers. The produce procured through collection centres is dispatched in cold trucks to centralized fruit and vegetable processing units. Produce is distributed from these units to outlets. Daily more than 100 tonnes of vegetables are distributed through this channel. The major climate hazards affecting distribution and retail operations are heavy rain and drought. It was reported that due to heavy rain losses of vegetables are high during November and December. The supplies of most vegetable types were reported to be affected by climate hazards.

Keels has more than 100 outlets island-wide with about 60 located within Colombo District. All vegetable procurement is done through its collectors operating through collection centres in the production areas. Cold trucks are used to transport produce from production regions to outlets. During short supply of produce due to rainfall and drought, prices usually increase and some vegetables such as beans and leafy vegetable supplies are badly affected. The losses of produce due to extreme weather are significant ranging from 10% to 20% based on the type of vegetable, e.g., carrot 8-9%, potato 3-4%, salad leaves 16-17% (Table 27).

Both supermarket chains reported that losses during transport due to extreme weather are negligible as transportation is done in cold trucks. None of the chains reported using early warning systems and information related to weather in their procurement decisions. According to supermarket chains, when transportation routes are inaccessible due to extreme weather, they use alternative routes to reach Colombo which invariably adds an extra cost to the price.

Table 27. Role of supermarkets in the supply chain of vegetables and impact of climate hazards on supplies

Factor	Supermarket chain	
	Cargills	Keels
Market share in Colombo District	5%-6%	5%
Procurement	10 collection centres/outgrowers (95% procurement)	100% with collectors based in Sooriyaweva, Pannegamuwa, Keppetipola, Thambuttegama, Jaffna and Sigiriya
Storage facility	None	None
Transport	In cold trucks	In cold trucks
Market price monitoring	-	None
Climate conditions affecting supply	Heavy rain and drought	Heavy rain and drought
Supply drops due to heavy rain/dry period/drought	Supply and quality affected	Pay high price (beans/leafy vegetables supply drop)
Spoilage due to extreme weather	Heavy rain: high spoilage (November, December)	Loss: Carrot 8%-9% Potatoes 3%-4% Salad leaves 16%-17%
Loss during transport	Negligible	Negligible
Climate damage to store	Rare	Rare
Early warning	Encourage climate smart farming	Not considered

Source: Stakeholder interview.

Figure 32 depicts the flow of upcountry and low country vegetables to the Colombo city region. The dominant role is played by the DECs in terms of facilitating an approximate volume of about 85% of vegetables into the Colombo city region. The supermarket chains also play an important role as an estimated volume of about 10% is supplied through their outlets established within the Colombo city region. Online doorstep delivery is an emerging trend and it is growing rapidly, especially in the context of the Covid-19 pandemic.

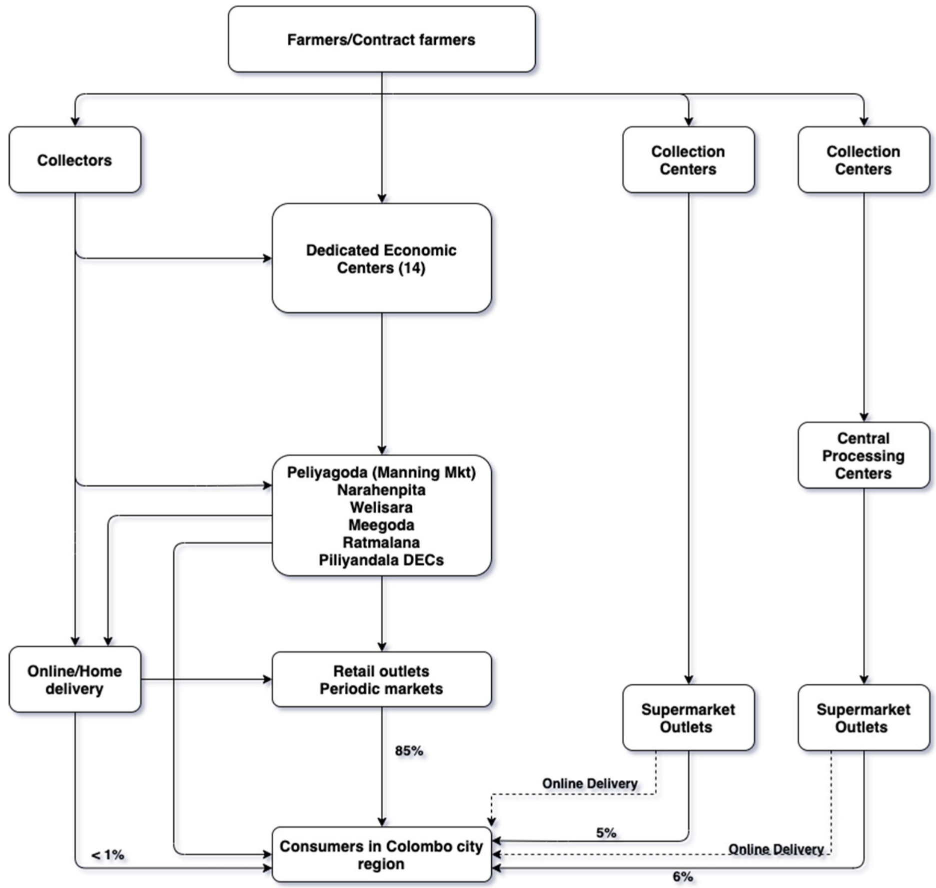


Figure 32. Upcountry and low country vegetable supply channels to the Colombo city region (traditional and supermarket)

Note: Volumes are estimates made based on stakeholder interviews.

Source: Authors.

4.2.9 Vegetable prices

There is no strong evidence to support the relationship between rainfall and retail prices of upcountry vegetables except for a few vegetable types such as leeks where there is a relationship between rainfall pattern and the Colombo retail price. When rainfall is high with a reasonable lag period, the prices of leeks increase. This is mainly due to high postharvest losses (spoilage) of leeks due to heavy rains in the production regions. The seasonal pattern of price fluctuation is evident from Figure 33, where during festive seasons in April and December, the prices increase. Monthly vegetable production statistics are not available to understand the relationship between production and prices. This is a serious data gap in understanding the response of retail market prices to climate hazards in production regions especially for upcountry vegetables as most of the upcountry vegetables are produced throughout the year.

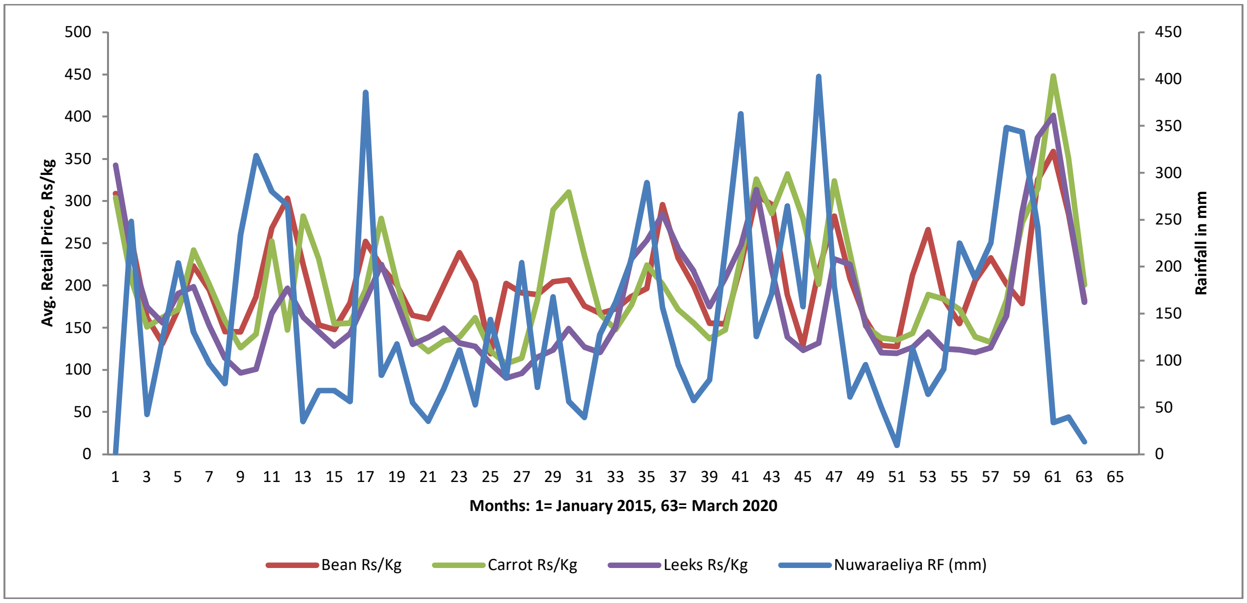


Figure 33. Monthly rainfall in Nuwaraeliya and Colombo retail prices of upcountry vegetables

Source: Compiled from AgStat agricultural statistics of various years.

The low country vegetable prices increased during the first quarter of 2017 due to low rainfall reported towards end of 2016. Towards end of 2018, the vegetable prices increased due to heavy rain disturbing harvesting and transportation. In addition to the impact of climate factors the regular seasonal price trends were also evident (Figure 34).

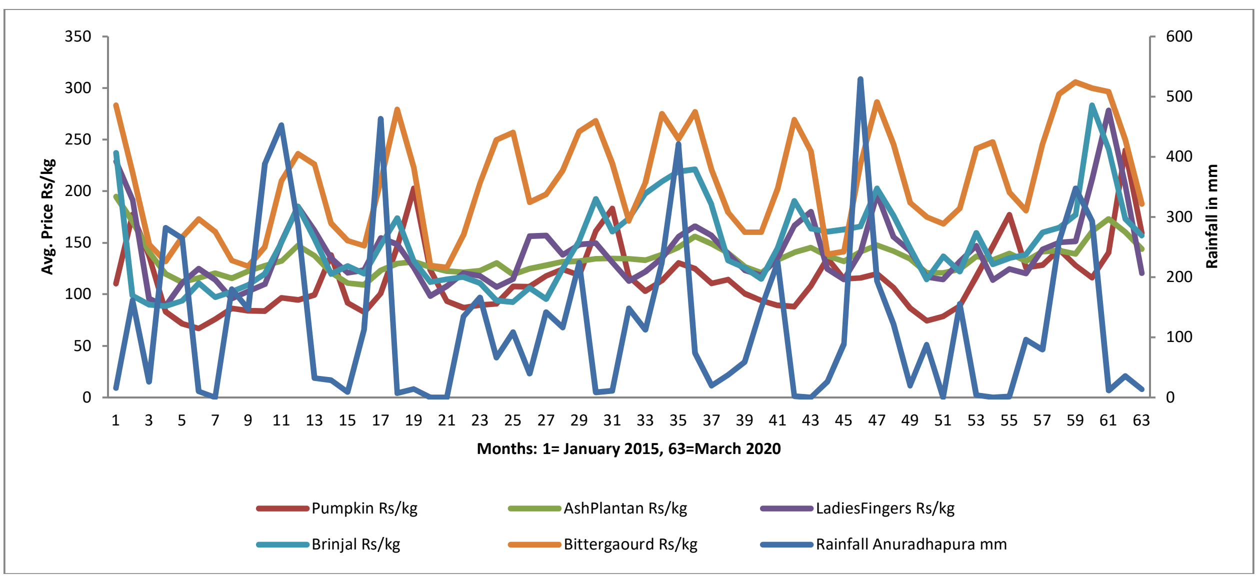
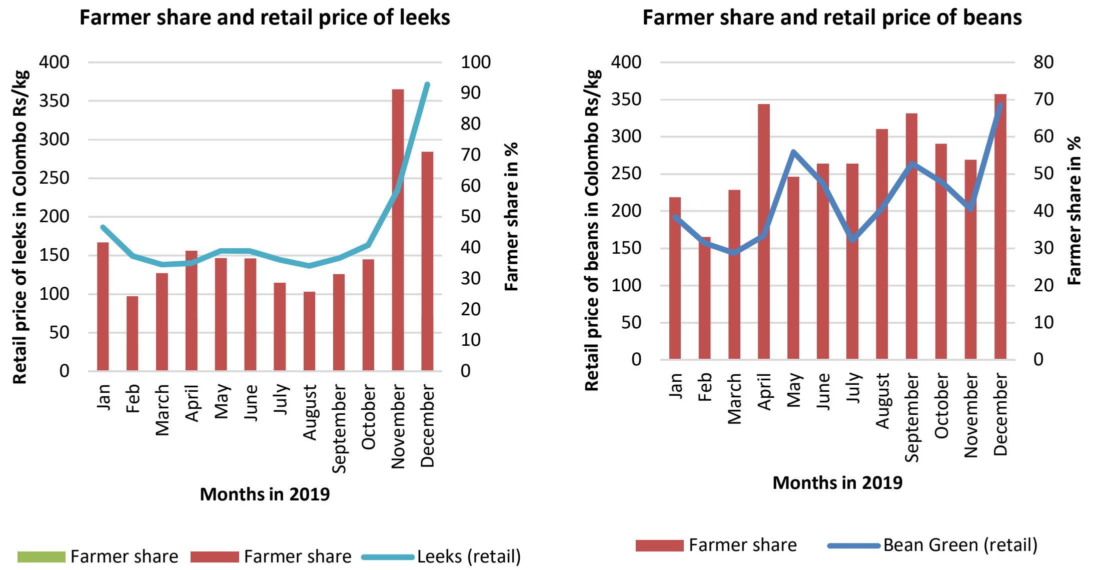


Figure 34. Monthly rainfall in Anuradhapura and Colombo retail prices of upcountry vegetables

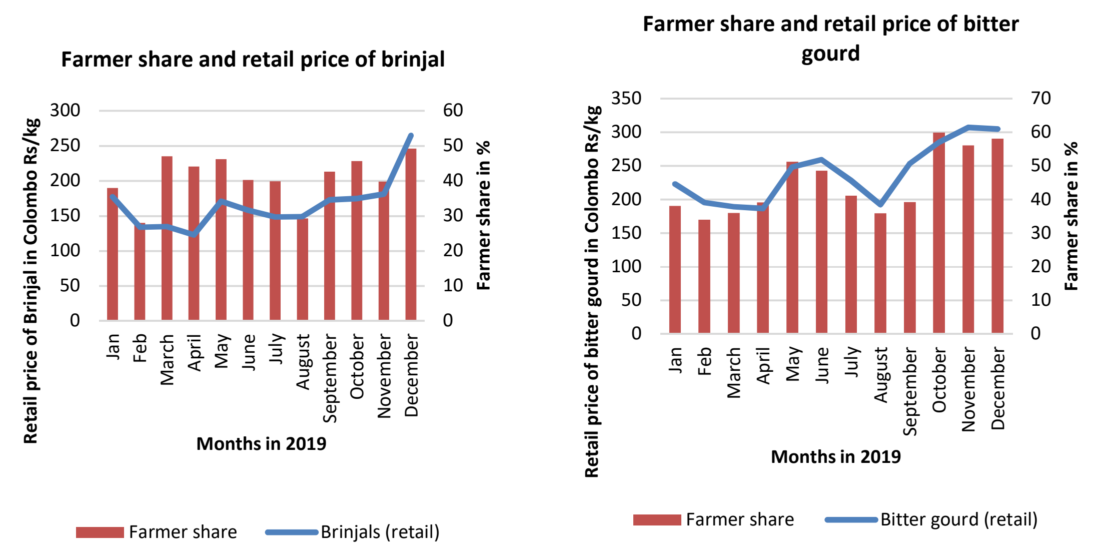
Source: Compiled from AgStat agricultural statistics of various years.

4.2.10 Farmer share of vegetables

Farmer share calculations reveal a general tendency of higher farmer share when retail prices increase implying that the farmers tend to get a higher share of the price when the market demand for both upcountry and low country vegetables is rising (Figure 35).



Upcountry vegetables



Low country vegetable

Figure 35. Farmer share of price of selected upcountry and low country vegetables

Note: Farmer share = (farmgate price/retail price) *100

Source: CBSL (2020).

Figure 36 illustrates an example of a brinjal value chain in marketing through DECs and other wholesale markets and how the share of the retail price is distributed among different players. It is clear that more than 60% of the share of the retail price is taken by the intermediaries thus showing the importance of shorter supply chains.

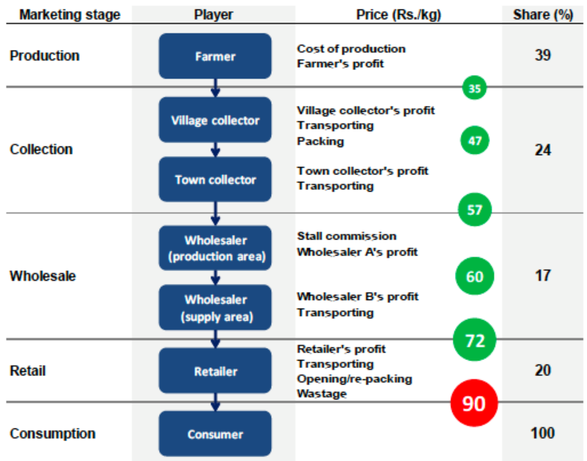


Figure 36. Example of a brinjal value chain and distribution of the retail price among different players

Source: JICA (2013).

4.2.11 Possible implications of climate hazards on vegetable supply chains and food security and nutrition

Per capita vegetable consumption is considerably low in Sri Lanka. Merely 3.5% of adults consumed the recommended five portions of fruits and vegetables per day (Jayawardane et al., 2013). Annual per capita availability of vegetables for consumption ranged from 134 kg to 146 kg during the period 2013 to 2017 (DCS, 2019b). However, annual per capita vegetable consumption remains at a very low level of 22 kg (60 g/day) (Silva et al., 2021). The recommended per capita intake of vegetables is between 225 g to 300 g per day. Daily intake of vegetables is vital for a healthy diet. Instead, 70% of Sri Lankan adults eat too much starchy food exceeding the upper limit of the recommendations for starch intake (Jayawardane et al., 2013). The significantly low level of vegetable consumption can be attributed to the seasonal price fluctuation and the low purchasing power of the poorer segments of the population. As shown in Table 28, the current consumption should rise by at least four to five fold to reach the recommended intake. Given the prices of vegetables and most importantly the price fluctuations it is unlikely that the poorer segments in the Colombo city region can afford the required quantities of vegetables to have a balanced diet.

Based on findings of the foregoing analysis it is reasonable to conclude that the impact of climate hazards on production and excessive postharvest losses along the supply chain are the main reasons for the unaffordability of vegetables among the poorer segments of the population including the poor in the Colombo city region.

Table 28. Household expenditure on vegetables in Colombo District, per capita consumption and recommended intake

Item	Household food expenditure share	Monthly household expenditure (LKR)	Current per capita consumption	Recommended per capita
Vegetables	8.0%	2,092	60 g	225-300 g

Note: Household (HH) size = 4 persons.

Sources: HIES (2016); Silva et al. (2020); Jayawardane et al. (2013).

There are serious food safety concerns with regard to upcountry vegetables. Farmers harvest vegetables immediately after application of agrochemicals without considering the recommended safety period between agrochemical application and harvesting (Padmajani et al., 2014). This practice is growing with the erratic rainfall pattern in the upcountry vegetable producing districts with food safety and health consequences for Colombo city region consumers. Some upcountry vegetable farmers cultivate vegetables for home consumption in a separate plot and avoid consuming from their commercial plots to prevent consuming agrochemical-contaminated vegetables.

4.3 IMPACT OF CLIMATE HAZARDS ON COCONUT PRODUCTION

- Drought-wind combined moisture stress is the major climatic factor contributing to production drop in the coconut triangle.
- The intensity of hazard is moderate in the coconut triangle.
- There is a clear relationship between annual coconut production and Colombo retail prices.
- In 2017/2018 coconut and coconut oil prices significantly increased due to low production attributed to climate hazards.
- Palm oil imports significantly increased in 2017/2018 leading to health risk.
- Vulnerable consumers cannot sustain the current consumption as household (HH) expenditure allocated for coconuts is not sufficient to meet the monthly HH coconut requirement of 30 nuts.
- High coconut oil prices prompt consumers to shift from coconut oil to palm oil or consume adulterated cooking oils leading to cancer and cardiovascular diseases.

4.3.1 Overview of coconut production

The main coconut-growing areas are concentrated in the districts of Kurunegala, Puttalam and Gampaha. These districts are known as the 'coconut triangle' that covers about 56% of the total coconut land area (MPIEA, 2020). Average annual coconut production from 2016 to 2019 ranged between 2 445 million nuts to 3 086 million nuts (Table 29). About 30% of production is processed and exported in value-added forms such as desiccated coconut and coconut oil.

Table 29. Production and cultivated extent of coconut from 2016 to 2019

Year	Extent (ha)	Production (million nuts)	Domestic consumption (million nuts)
2016	440.457	3,011	2,119 (70.4%)
2017	452,550	2,445	1,700 (69.5%)
2018	499.125	2,623	1,847 (70.4%)
2019	503.452	3,086	-

Note: Value in parentheses is the percentage locally consumed.

Source: MPIEA (2020).

4.3.2 Identification of hazards

Table 30 shows the prevalence of climate hazards in the three main districts in the coconut triangle. Wind and droughts are more prominent in Kurunegala and Puttlam districts. In Gampaha district, floods and winds are more prominent.

Table 30. Prevalence of climate hazards on coconut production

District	Heavy rain	Floods	Landslides	Wind	Drought
Gampaha (41 events)	7 (17.1%)	14 (34.1%)	1 (2.4%)	29 (70.7%)	7 (17.1%)
Kurunegala (47 events)	6 (12.8%)	13 (27.7%)	0	32 (68.1%)	21 (44.7%)
Puttlam (46 events)	6 (13.0%)	12 (26.1%)	0	37 (80.4%)	10 (21.7%)

Source: Authors.

Table 31 indicates the intensity of hazards in each district of the coconut triangle.

Table 31. Hazard levels in districts

District	Hazard				
	Severe	Strong	Moderate	No impact	Total
Gampaha	9	9	22	1	41
	22.0%	22.0%	53.7%	2.4%	
Kurunegala	3	19	23	2	47
	6.4%	40.4%	48.9%	4.3%	
Puttalam	5	8	32	1	46
	10.9%	17.4%	69.6%	2.2%	

Note: Severe = loss of life plus other damages; very strong = loss of life; strong = injury or other health impacts; moderate = loss of property.

Source: Authors.

Vulnerability to extreme weather events is moderate in Kurunegala and Puttalam districts. Coconut production is rated less vulnerable in Gampaha District (Table 32). The content analysis results confirm the vulnerability ranking estimates of the Ministry of Environment as illustrated in the Figure 37.

Table 32. Vulnerability levels in districts

District	Vulnerability			Total
	Highly vulnerable	Moderately vulnerable	Less vulnerable	
Gampaha	0	4	37	41
		9.8%	90.2%	
Kurunegala	0	45	2	47
		95.7%	4.3%	
Puttalam	0	41	5	46
		89.1%	10.9%	

Source: Authors.

Kurunegala District has the highest risk score among the three districts in the coconut triangle in the reference years due to high sensitivity of the crop to climate hazards (Table 33). The relatively high level of sensitivity in Kurunegala District could be attributed to the adverse effect of climate hazards such as wind and drought due to poor water management and conservation which needs further investigation.

Table 33. Scores related to risk and vulnerability by production regions

District	Hazard	Exposure	Sensitivity	Capacity	Vulnerability	Risk
Gampaha	-1.85	-1.0	-1.07	0.98	-0.09	-2.95
Kurunegala	-1.56	-0.98	-2.15	1.04	-1.10	-3.64
Puttalam	-1.48	-1.10	-1.16	1.06	-1.02	-3.50

Source: Authors.

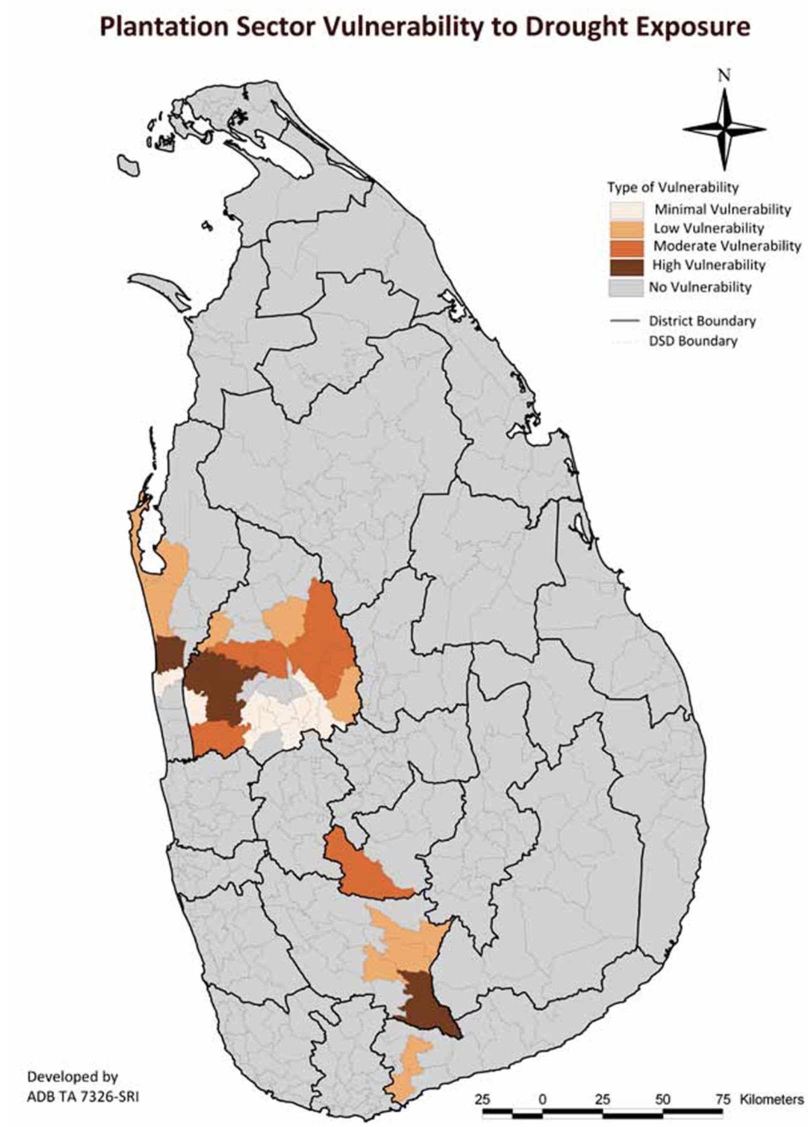


Figure 37. Vulnerability of coconut production regions to drought

Source: Nandana et al. (2011).

In all three districts of the coconut triangle, the level of risk is rated between moderate to low (Table 34).

Table 34. Risk levels in the coconut triangle

District	Risk			Total
	High risk	Moderate risk	Low risk	
Gampaha	0	10	31	41
		24.4%	75.6%	
Kurunegala	0	25	22	47
		53.2%	46.8%	
Puttalam	2	13	31	46
	4.3%	28.3%	67.4%	

Source: Authors.

Coconut production in the current year is highly dependent on the rainfall pattern of the previous year. The rainfall during February, June, July, September and December in the preceding year to the harvest is critical for the following year's production (Peiris et al., 2008). According to the rainfall records of Kurunegala District in 2016 and 2017, it is clear that the monthly rainfall of the critical months mentioned previously were below the average with implications for production drop (since Kurunegala District production statistics are not available, ANCP is taken as a proxy) in 2017 and 2018 (Figure 38). The production drop in the months of 2017 and 2018 ranged from 3% to 25% and 5% to 19% respectively as presented in Table 35. The favourable rainfall that prevailed in 2018 led to better production in all the months of 2019 (Figure 39).

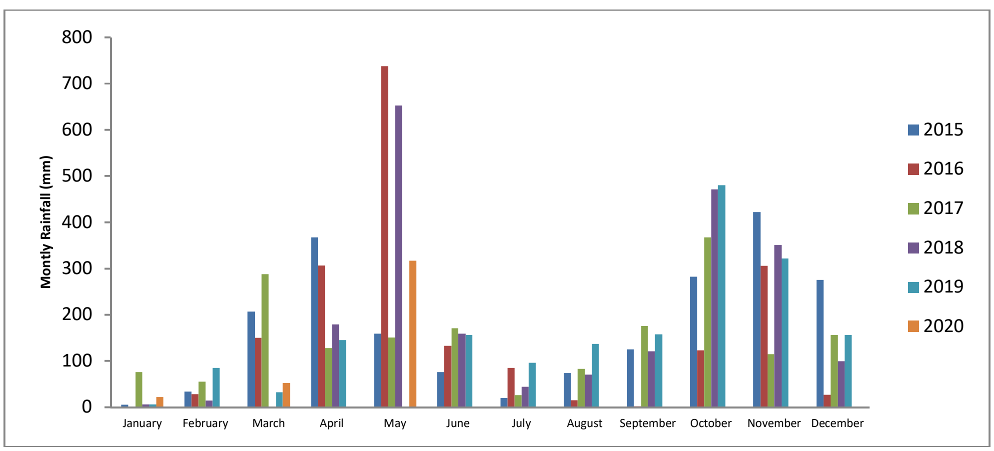


Figure 38. Monthly rainfall in Kurunegala from 2015 to 2020

Source: Compiled from AgStat agricultural statistics of various years.

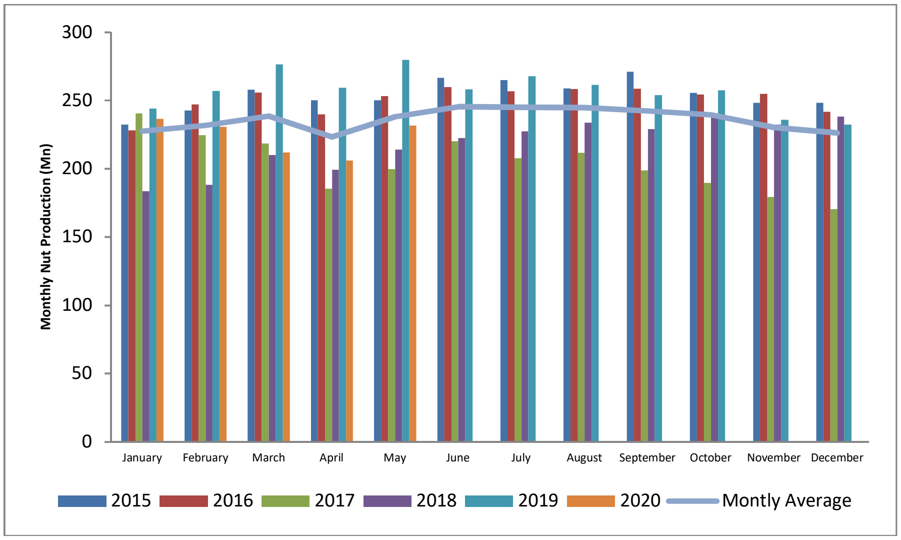


Figure 39. Monthly national coconut production from 2015 to 2020

Source: Compiled from CBSL Monthly Economic Indicators for various months.

Table 35. Percentage change of monthly NCP in 2017 and 2018

Months	Monthly five-year average (production in millions)	2017 (% change)	2018 (% change)
January	227.53	5.70	-19.40
February	231.70	-3.11	-18.69
March	238.52	-8.39	-11.87
April	223.32	-16.98	-10.71
May	238.17	-16.07	-10.06
June	245.44	-10.32	-9.35
July	244.92	-15.20	-7.15
August	244.88	-13.51	-4.57
September	242.30	-17.99	-5.41
October	239.54	-20.85	0.44
November	230.20	-22.11	0.96
December	226.28	-24.65	5.27

Source: CBSL Monthly Economic Indicators for various months.

According to Table 36, the overall hazard scores are highly negative, and the risk scores were high in 2016 and 2017; this corresponds with low annual national coconut production 2017 and 2018. Moreover, the hazard score was less negative in 2018; this corresponds with high production in 2019. These results show how climate hazards impact on coconut production in the coconut triangle.

Table 36. Hazard, vulnerability and risk scores by year for major coconut-producing districts

Year	Average score Std. Dev		
	Hazard Score	Vulnerability Score	Risk Score
2015	-1.29	-0.57	-2.71
	0.83	0.51	0.99
2016	-2.0	-0.68	-3.68
	1.41	1.17	2.03
2017	-2.05	-0.93	-3.9
	1.48	1.56	2.70
2018	-1.44	-0.82	-3.18
	0.96	0.67	1.34
2019	-1.58	-1.03	-3.74
	0.96	0.84	1.48
2020	-0.97	-1.50	-3.47
	0.72	1.26	1.48
Overall	-1.58	-0.96	-3.53
	1.18	1.14	1.87

Source: Authors.

4.3.3 Impact of temperature on coconut production

The maximum ambient temperature in the afternoon is known to be a most significant variable influencing coconut production (Peiris et al., 1997). The ambient temperature in March 2016 exceeded 36^0C possibly this too would have contributed to the drop of production in 2017 (Figure 40).

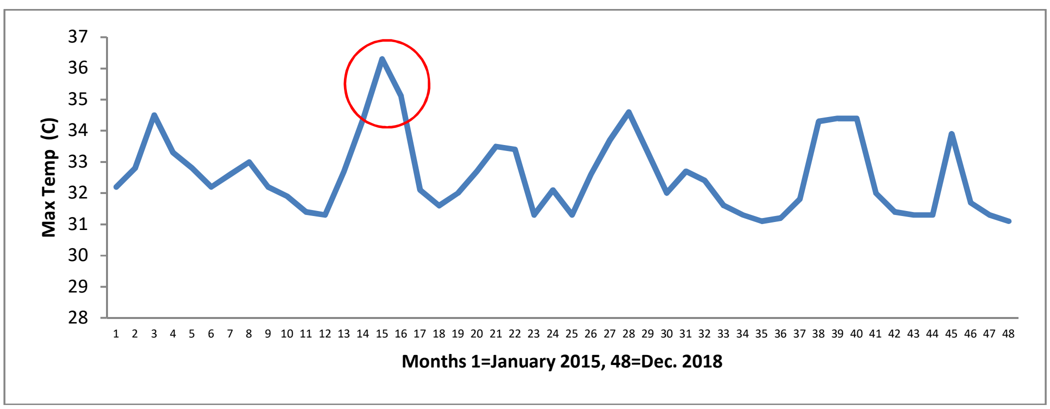


Figure 40. Maximum temperature in Kurunegala District from 2015 to 2019

Source: Compiled from AgStat agricultural statistics of various years.

4.3.4 Impacts of climate hazards on coconut collection, processing and distribution

According to the levels of hazard, vulnerability and risk reported through the content analysis there was not enough evidence to support that coconut collection, processing and distribution are impacted by climate hazards.

4.3.5 Impact of climate hazards on coconut price, consumption, food security and nutrition

There is a clear pattern between annual national coconut production (ANCP) and the Colombo retail price. During the periods of lean production in 2017 and 2018, the prices increased significantly (Figure 41). Coconut exports also have some impact on local retail prices as annual exports do not drop parallel to drops in the annual production.

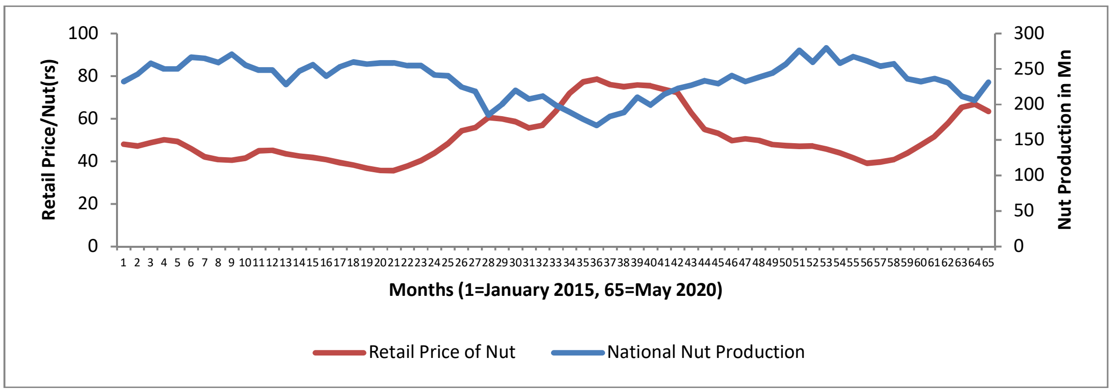


Figure 41. Coconut production and Colombo retail price from 2015 to 2020

Source: Compiled from HARTI Food Commodities Bulletin for various weeks and CBSL Economic Indicators for various months.

The average export is around 20% of the ANCP. In 2017, despite the drop in the ANCP, the proportion of exports remained relatively constant (Figure 42). However, it dropped in 2018 to 14%.

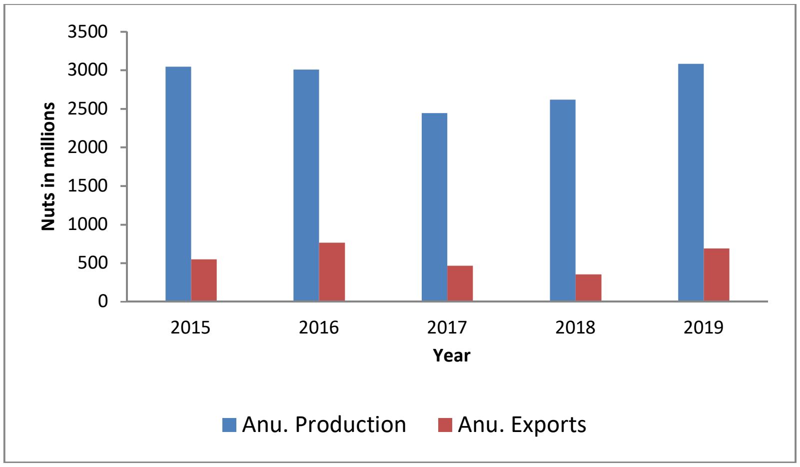


Figure 42. ANCP vs coconut exports from 2015 to 2019

Source: Compiled from CBSL Social and Economic Statistics (2020).

Table 37. Household expenditure on coconuts in Colombo District, per capita consumption and recommended intake

Item	Household food expenditure share (%)	Monthly household expenditure (LKR)	Current per capita consumption	Monthly household coconut requirement	Recommended per capita
Coconut	4.5	1,166	7.4 nuts	30 nuts	N/A

Note: Household size = approximately 4 persons.

Source: HIES (2016).

Coconut oil production and exports have remained constant over time despite coconut production dropping during 2017 and 2018; this affected coconut consumption due to price hikes. This could have possibly led to substitution of fresh coconut use by imported palm oil (Figure 43).

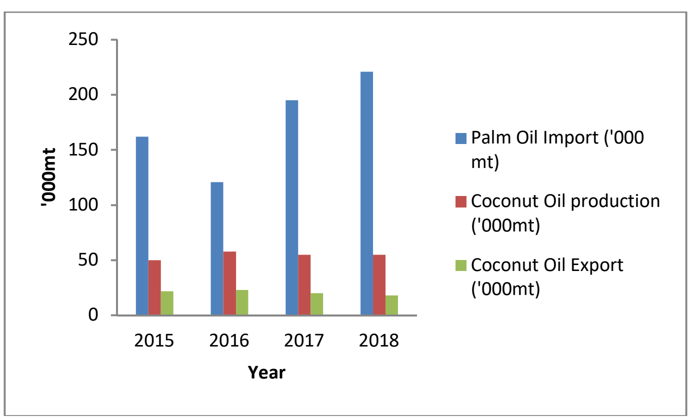


Figure 43. Coconut oil production, exports and palm oil imports from 2015 to 2018

Source: FAOSTAT.

Health issues of palm oil
When the local coconut production drops, as experienced in 2017 and 2018, the coconut oil prices escalate (Figure 44); as a result people tend to use palm oil as a substitute for coconut oil. Lauric acid content in palm oil is very low compared to coconut oil (Suryani et al., 2020). This could have implications for health especially, people become prone to cardiovascular diseases as more long chain saturated fatty acid is present in palm oil (Nethasinghe, 2017). Further, due to a shortfall of coconut oil and high prices, adulterated cooking oils become available in the market. Especially in 2017, a significant amount of palm oil not suitable for human consumption was confiscated (Nethasinghe, 2017).

Figure 44. Coconut oil retail price behaviour from 2015 to 2018

Source: CEIC database: http://www.ceicdata.com/

Figure 45 explains the pathway of climate hazards on coconut and coconut oil consumption and its implications for health and nutrition. Given that the highest food insecure population lives in Colombo (Mayadunne & Romeshun, 2013), the vulnerable groups in the Colombo city region will have difficulties in affording coconuts and coconut oil.

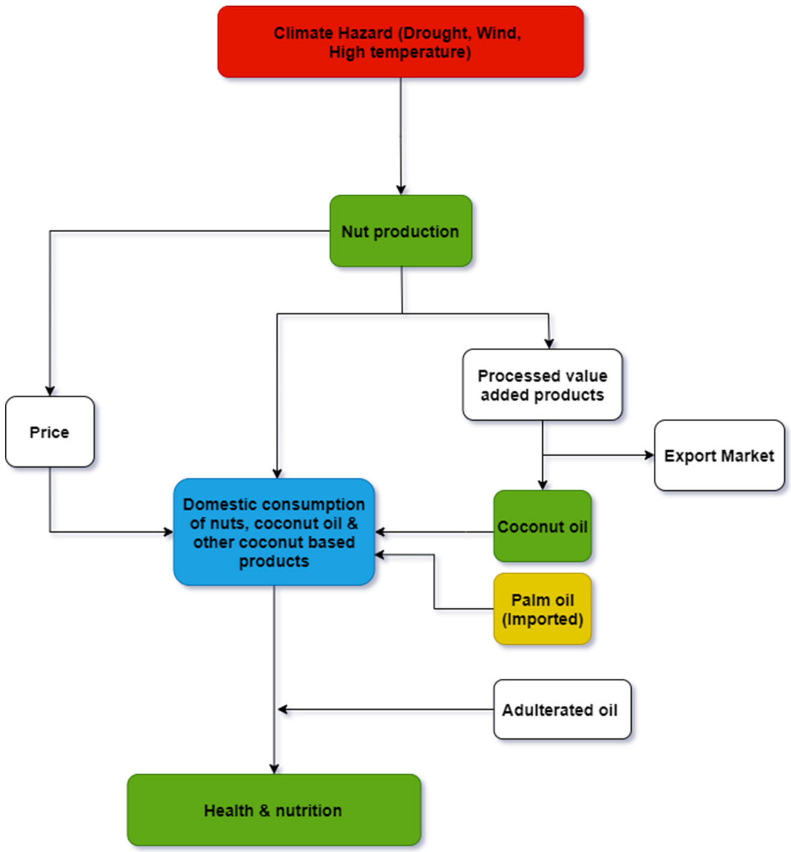


Figure 45. Cascading effects of climate hazards on coconut and coconut oil consumption and health and nutrition

Source: Authors.

4.4 IMPACT OF CLIMATE HAZARDS ON THE MARINE FISH SUPPLY CHAIN

- The main climate hazards that impact marine fishing are wind, cyclones and heavy rains.
- The prices of major fish varieties move above the average when the hazard intensifies.
- Fish supplies to Peliyagoda fish market drop by as much as 40% to 50% and prices fluctuate in the range of 30% to 40% compared to a normal day due to adverse weather in the production regions.
- Extreme weather conditions can contribute to postharvest losses of fish as high as 40%.
- Among the three fishing belts assessed, the northern fishing belt is the most vulnerable and risky region due to poor infrastructure.
- The fishing fleet lacks multiday fishing vessels that can withstand harsh weather.
- Food safety and quality in the domestic supply chains are very poor.
- Fish is not affordable to the average consumer in the city region; hence, it is a challenge for food and nutrition security, especially protein malnutrition as fish provide 53% of the animal protein requirement.

4.4.1 Overview of marine fish production

Fish plays a significant role in food and nutrition security as it fulfills the bulk of the animal protein requirements of the population. Marine fish production accounts for more than 80% of national fish production. All 15 coastal districts contribute to marine fish production. Landing sites and fisheries harbours in Puttlam, Galle and Hambantotta districts are the predominant contributors to national marine fish production.

Climate change has a profound impact on the marine fisheries sector. Adverse weather in the production regions readily translates into supply shortfalls and price increases in the city region. Marine fish reach consumers in the city region through a number of channels among which the central fish market complex in Peliyagoda acts as the main fish wholesale distribution hub of the city region.

4.4.2 Identification and impact of hazards on production and price

The implications of climate change on marine fisheries production are already being felt. The major climate hazards that impact marine fishing are wind, cyclones and heavy rains. As shown in Table 38, from 2015 to 2020, 71 wind/cyclone and 109 heavy rain events affected fish production regions. Distribution, wholesale and retail activities were affected by 109, 93 and 55 heavy rain, flood and landslide events respectively. Consumption was possibly affected by 16 and 15 flood events reported in Colombo city region according to the content analysis results (Table 38).

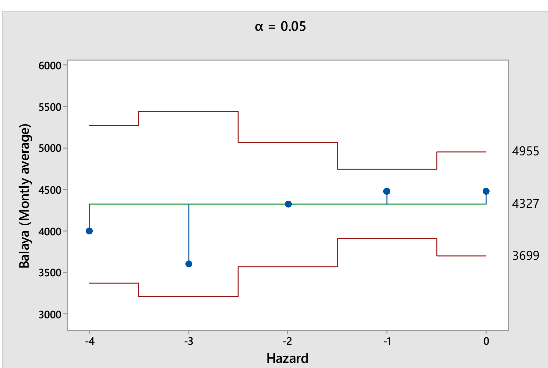
Table 38. Hazard events affecting the marine fish supply chain from 2015 to 2020

Node	**Hazards**			
	Wind/cyclones	Heavy rain	Floods	Landslides
Production	71 (100%)	109 (99.1%)	[redacted]	[redacted]
Distribution, wholesale and retail	[redacted]	109 (99.1%)	93 (100%)	55 (98.2%)
Consumption	[redacted]	16 (14.5%)	15 (16.1%)	[redacted]

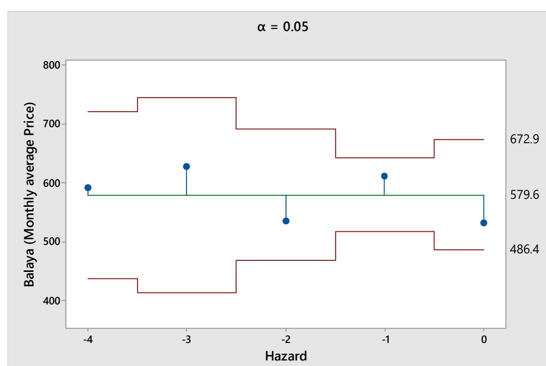
Note: Hazard events were identified based on the content analysis; the percentages in parentheses indicate the actual hazard events out of the total hazard events impacting a given node.

Source: Authors.

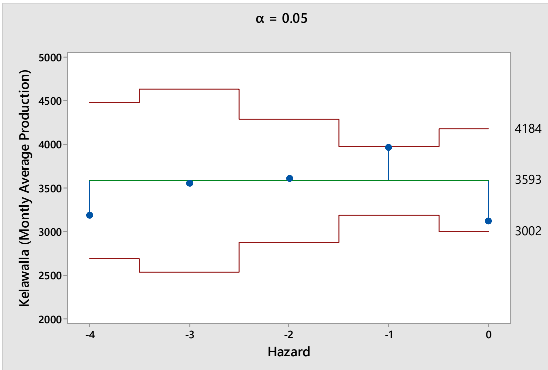
The hazard scores calculated based on the severity of the climate hazard show a mediocre relationship with the monthly average production of two major fish verities namely skipjack tuna and yellow fin tuna. It is clear that when the hazard score reaches -3 to -4, the production falls below average (Figure 46a and Figure 46c). However, as shown in Figure 46e, the all-billfish production often remains above average despite the intensity of the hazard; a possible explanation would be that this fish variety is mostly harvested from the deep sea using multiday vessels. The prices of all three fish varieties move above the average when the hazard intensifies. However, the price fluctuation of all-bill fish is relatively low compared to the other two varieties as evidenced by the higher coefficient of determination (Figure 50). Moreover, the all-bill fish price rises steeply compared to the other two fish varieties as indicated by the regression coefficient; this could be due to the high demand for this variety when the other two fish varieties are in short supply due to the impact of climate hazards.



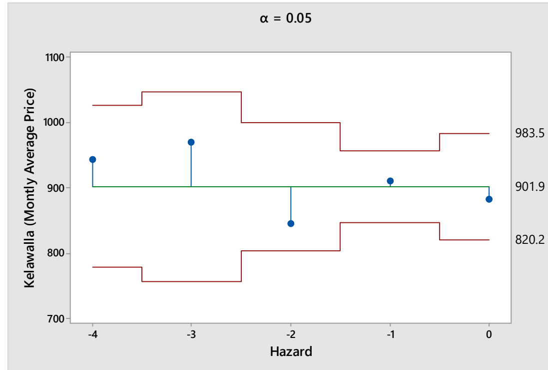
a. Hazard vs production (tonnes) for skipjack tuna



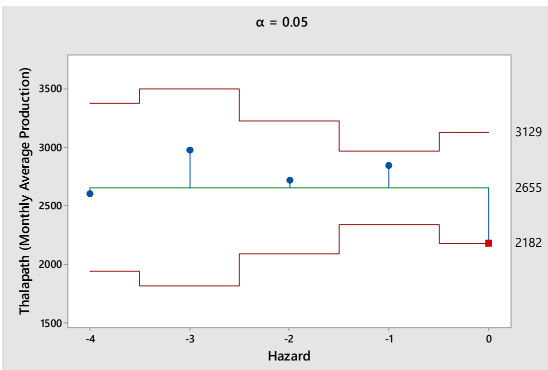
b. Hazard vs price for skipjack tuna



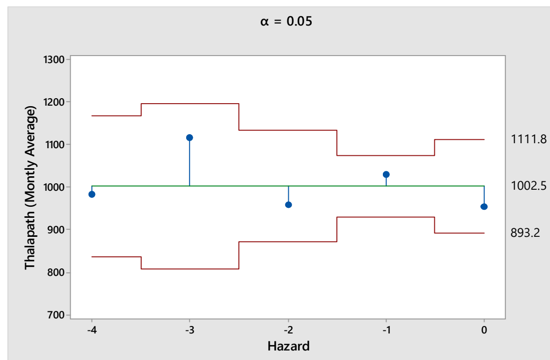
c. Hazard vs production (tonnes) for yellow fin tuna



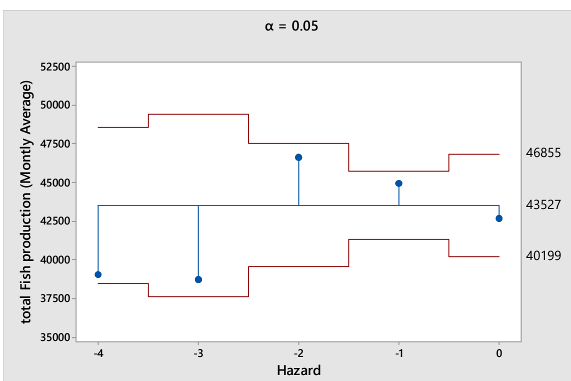
d. Hazard vs price for yellow fin tuna



e. Hazard vs production (tonnes) for all-bill fishers



f. Hazard vs price for all-bill fishers



g. Hazard vs national monthly marine fish production

Figure 46. Hazard score vs monthly fish production and average monthly Colombo retail price

Note: The climate hazard was quantified based on a scale where 0 = no effect, -1 = damage and loss to property, -2 = injury, or other health impacts, -3 = loss of life, -4 = loss of life and any stated damage.

Source: Authors.

The impact of climate hazards in 2015 and 2019 can be clearly seen as the national fish production shows a drop in the respective years (Figure 47).

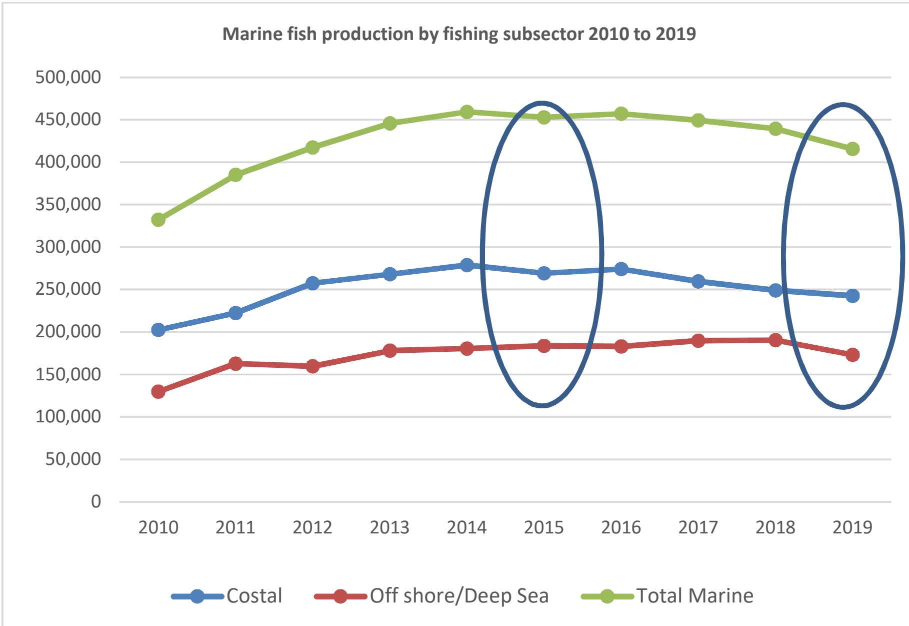


Figure 47. Total national marine fish production from 2010 to 2019

Source: Compiled from Fisheries Statistics 2020, Ministry of Fisheries

4.4.3 Risk and vulnerability of the fish supply chain

Marine fish production increased up to 2014 due to significant contributions from the coastal fishing subsector (Ministry of Fisheries, 2020). However, in subsequent years, coastal fishing declined due to climate hazards. Notably, in 2019, marine fish production significantly declined mainly driven by the deep-sea subsector, due to disturbances to fishing activities as a result of frequent cyclonic conditions in the Indian Ocean. There were 57 weather alerts issued to fishers in 2019 compared to 43 in 2018. This is substantiated by the relatively high-risk score for the 2019 obtained from the content analysis (Figure 46). The comparatively low risk score for 2019 compared to 2015 can be attributed to capacity enhancement through pre- and post-hazard event initiatives such as providing early warnings to fisheries associations and compensation and emergency relief given to affected fishermen families. This is reflected in the higher capacity score recorded in 2019 relative to the capacity score in 2015. This implies that production risk can be mitigated by building fishermen capacity, especially by building pre-event capacity.

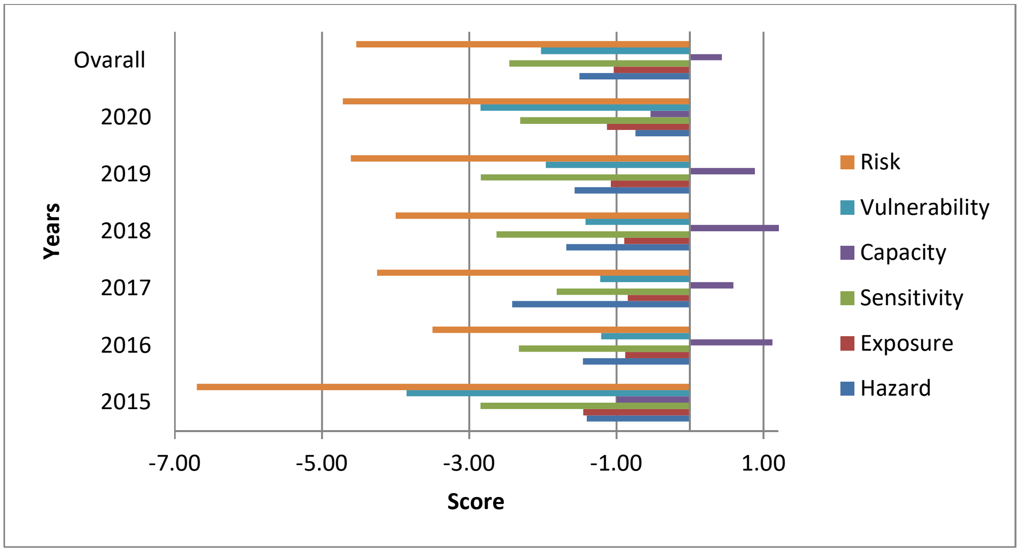


Figure 48. Annual marine fish supply chain risk assessment from 2015 to 2020 based on content analysis
Source: Authors.

The capacity of fishermen remains relatively low as indicated by the capacity and vulnerability scores of fish producers depicted in Figure 48. The low capacity and high vulnerability can be attributed to a number of factors ranging from socio-economic status and access to fishing gear and infrastructure. Fishing infrastructure such as membership in fisheries organizations and the operating fishing fleets are good proxies of fishermen's capacity. As shown in Table 41, Out-board engine Fibreglass Reinforced Plastic Boats (OFRP) are the main type of fishing boats used by fishers. These OFRP boats are known to be highly vulnerable to extreme weather such as high winds and storms (De Silva, 2016). It is also clear that only 11% of the fishing fleet comprises modern boats suitable for deep-sea fishing and able to withstand stormy weather.
The negative capacity in 2020 can be attributed to the lack of preparedness to face the Covid-19 pandemic as poor awareness and lack of information on the evolving pandemic took fish supply chain actors by surprise.
As shown in Table 39, the production regions are classified into Western (WFB), Southern (SFB) and Northern (NFB) fishing belts. However, the Eastern fishing belt is not considered here due to its low contribution to the Colombo city region in terms of fish supplies.

Table 39. Operating fishing boats by fishing region in 2019

Fishing belt	IMUL + IDAY	OFRP	MTRB	NTRB	NBSB	Total boats
WFB	1,169 (9%)	6,307 (50%)	195 (2%)	4,532 (36%)	304 (2%)	12,507
SFB	2,786 (35%)	2,467 (31%)	607 (8%)	1,839 (23%)	215 (3%)	7,914
NFB	1,057 (4%)	15,516 (61%)	1,387 (6%)	6,535 (26%)	558 (2%)	25,053
Total	5,012 (11%)	24,290 (53%)	2,189 (5%)	12,906 (28%)	1,077 (2%)	45,474

Note: IMUL = Inboard Multi-day Boats, IDAY = Inboard Single-day Boats, OFRP = Out-board engine Fibreglass Reinforced Plastic Boats, MTRB = Motorized Traditional Boats, NTRB = Non-motorized Traditional Boats NBSB Non-Motorized Beach Seine Crafts

Source: Calculated by the authors based on Fisheries Statistics 2020, Ministry of Fisheries.

The NFB is the most poorly equipped region with modern fishing boats. This is evidenced by the relatively higher vulnerability and risk scores of the NFB (Figure 49).

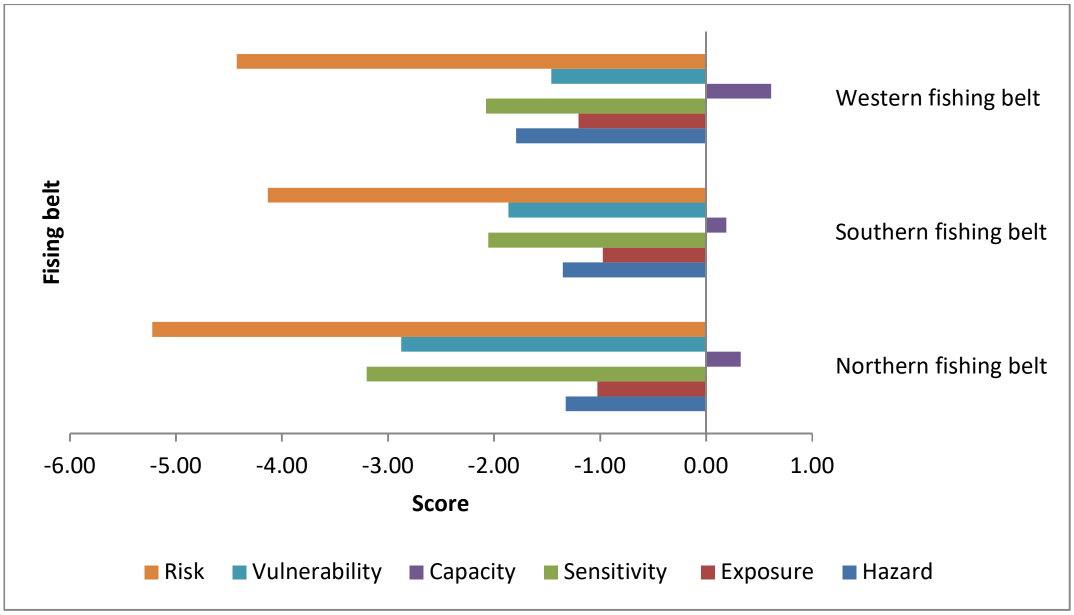


Figure 49. Risk assessments for major marine fish production regions

Note: Southern and Western fishing belts are the main regions supplying fish to Colombo city region.

Source: Authors.

Fisher collectives such as cooperatives are known to play a significant role in enhancing the resilience of small-scale fishing households (Amarasinghe & Bavinck, 2011). However, the affiliation of fishers to collectives stands at a very low level in the SFB with only 32% of fishers holding membership in fisheries organizations (Table 40). This number stands at 63% in the WFB, which implies that they are better organized compared to the other two fishing regions.

Table 40. Number of fishers, fishers' organizations, membership and membership as a percentage of fishers in 2019

Fishing region	Fishers	No. of fisheries organizations	No. of members	Members as a % of total fishers
WFB	28,750	275	18,042	62.75
SFB	54,080	212	17,532	32.42
NFB	61,410	294	26,577	43.28

Note: WFB = Western fishing belt; SFB = Southern fishing belt; NFB Northern fishing belt

Source: Compiled from Fisheries Statistics 2020, Ministry of Fisheries.

The production node becomes moderately vulnerable as a result of reported wind/cyclone events and heavy rain events. In the events of heavy rain and floods in the Colombo city region, consumption is likely to become vulnerable mainly due to the loss of livelihoods of the city region consumers dependent on daily wage earnings from the informal sector (Table 41).

Table 41. Vulnerability intensity by hazard and supply chain nodes

Node	Hazard	Vulnerability			Total
		Highly vulnerable	Moderately vulnerable	Less vulnerable	
Production	Wind/ cyclone	22 (30.99%)	29 (40.85%)	20 (28.17%)	71
	Heavy rain	24 (22.02%)	57 (52.29%)	28 (25.69%)	109
Consumption	Heavy rain	5 (31.25%)	10 (62.50%)	1 (6.25%)	16
	Flood	5 (33.33%)	10 (66.67%)	0 (0.00%)	15

Source: Authors.

Of the wind/cyclone events, around 70% has contributed to increasing the risk at the production node, while around 65% of heavy rain events has contributed to the same. Potential risk at the consumption node is likely to be influenced by 69% and 87% of heavy rain and flood events in the Colombo city region respectively (Table 42).

Table 42. Risk intensity by hazard and supply chain nodes

Node	Hazard	Risk			Total hazard events
		High risk	Moderate risk	Low risk	
Production	Wind/cyclone	20 (28.17%)	27 (38.03%)	24 (33.80%)	71
	Heavy rain	28 (25.69%)	42 (38.53%)	39 (35.78%)	109
Consumption	Heavy rain	5 (31.25%)	6 (37.50%)	5 (31.25%)	16
	Flood	6 (40.00%)	7 (46.67%)	2 (13.33%)	15

Source: Authors.

4.4.4 Implications of climate hazards on fish processing, storage, wholesaling and retailing

Extreme weather conditions can contribute to postharvest losses of fish as high as 40%. This is further aggravated by lack of facilities such as chilled storage and ice supplies at most of the fish landing sites. Further, the fishery harbours, anchorages and landing sites are poorly equipped and lack basic facilities.

There were 90 ice plants in operation in 2019 with production capacity of 3,333 tonnes/day. Ice plants and cold storage facilities are operated by Ceylon Fisheries Corporation (CFC). As shown in Table 43, the WFB has the most ice demand met while most of the ice plants are located in the SFB. The least number of ice plants that is only able to meet just 44% of demand is located in the NFB. This could be another reason for the high risk of the NFB as a production region as highlighted before.

Table 43. Number of ice plants, production capacity vs demand for ice in 2019

Fishing region	No of plants	Daily production capacity (tonnes)	Daily demand (tonnes)	Production as a % of demand
WFB	29	1,152	1,252	92
SFB	40	1,488	2,440	61
NFB	21	693	1,577	44

Source: Compiled from Fisheries Statistics 2020, Ministry of Fisheries.

In the fish processing sector for domestic consumption, local canned fish production can play a vital role. In recent years, canned fish production has increased with five processing plants becoming operational with a daily output of about 150,000 cans per day ("Development of local", 2020).

Local small-scale fish processing that adopts traditional methods such as salting, drying and smoking can be affected by extreme weather such as heavy rains (De Silva, 2016). Processors, exporters and supermarket chains have better infrastructure for transport, processing and storage. However, their contribution to strengthening the domestic fish supply chain is minimal.

The Peliyagoda fish market considered as the national wholesale fish market in Sri Lanka with about 154 wholesale fish stalls and 15 retail stalls is the main distribution hub of fish in the Colombo city region. On an average day about 350,000 kg of fish are received and about 25% of national fish production is channeled through this market ("Development of local", 2020). The main sources of fish are the SFB and WFB. Interviews with wholesalers in the Peliyagoda fish market revealed that due to climate hazards in the production regions, fish supply could go down by as much as 40% to 50% compared to a normal day. The prices are known to fluctuate in the range of 30% to 40% due to adverse weather in the production regions. The wastage of fish is around 10%; of the unsold stocks 10% to 20% is sold for processing of dry fish. It was reported that the impact of climate extremes on operations was minimal. However, distribution by retailers to the city region is affected by climate extremes.

The Peliyagoda fish market is equipped with some reasonable facilities such as cold storage. Three cold rooms are available with a storage capacity of 5,000 kg. However, there are food safety and quality concerns that need serious attention. In Sri Lanka, enforcement of food safety and quality standards are limited only to the fish export value chains and a few supermarket value chains (Gunasinghe et al., 2015). There is a lack of quality and food safety consciousness among domestic fish supply chain actors resulting in poor quality and food safety-compromised fish reaching the consumer with possible health implications. Moreover, malpractices such as adulterating the fish purchases with inedible fish parts reduce the amount available for consumption.

4.4.5 Impact of climate hazards on food security and nutrition in the Colombo city region

According to the food balance sheet, per capita fish availability is calculated based on fish supply and population which stands at 32 kg/year. This is an overestimation because it is based on raw fish including inedible parts. Therefore, the available per capita fish supply is 19.2 kg/year which is not sufficient to meet the current requirement of 36.5 kg/year/person (considering a 0.6 yield factor and the dietary recommendation of 21.9 kg/year/person, or 60 g/person/day based on the real dietary intake of the people according to Silva et al. (n.d). Given the average household size of 4, an average family has to consume 7.2 kg of cooked fish per month which is equivalent to 12 kg of fresh fish (assuming a yield factor of 0.6). According to the 2016 HIES, on average a household spends about LKR 3,183/month for fish and dry fish consumption. If a household is to fulfill the daily dietary requirement, fish should be available at a much lower price than the current retail market price. Given the nominal price of fish and the inflationary price escalation as shown in Figure 50, it would be barely possible to achieve at least one-third of the dietary recommendations of fish (Figure 51).

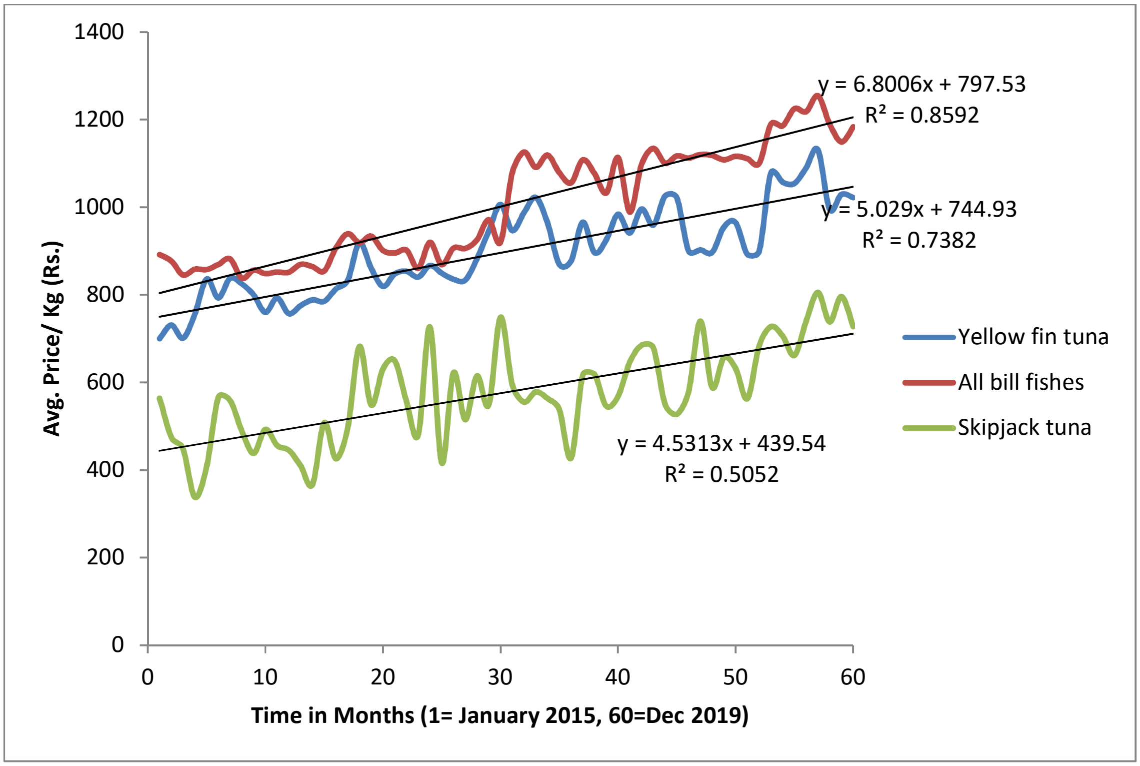


Figure 50. Price trends of major fish varieties in Peliyagoda fish market from 2015 to 2019

Source: Compiled from HARTI Monthly Food Commodities Bulletin, various months.

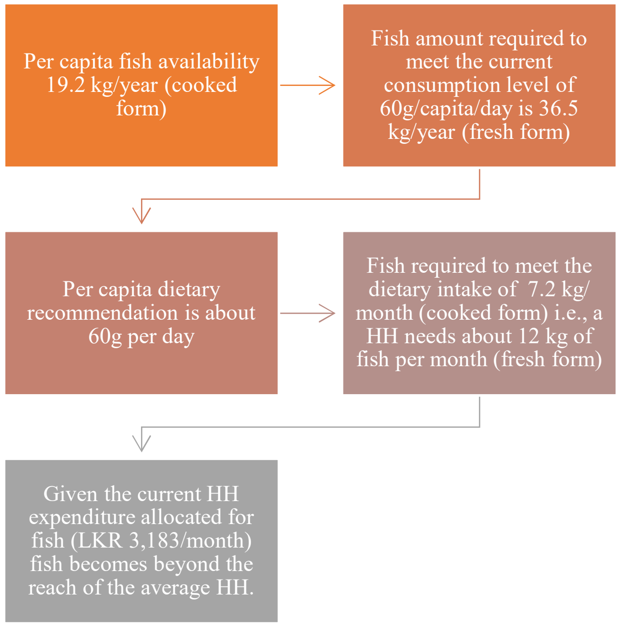


Figure 51. Affordability of fish to an average family in the city region

Source: Authors.

The situation could be worse when it comes to the urban poor in the Colombo city region with implications for animal protein intake as fish contributes to about 53% of animal protein intake (Figure 52). This implies that climate hazards in the fishing regions can have a direct impact on protein malnutrition in the Colombo city region.

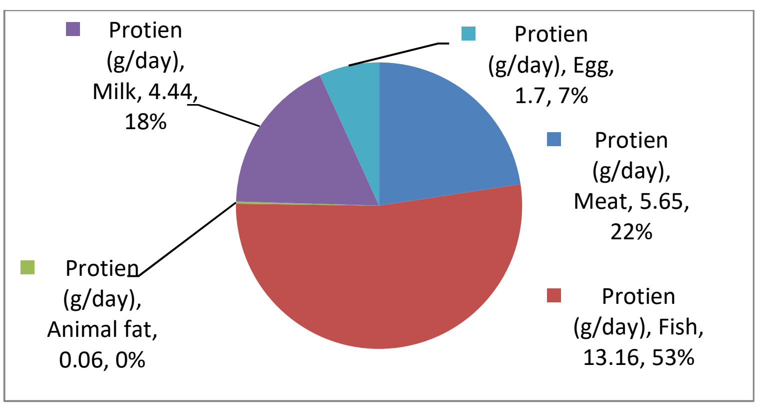


Figure 52. Proportion of different categories of animal origin in total animal protein intake

Source: Silva & Dematawewa (2020).

Figure 53 shows the cascading effect of climate hazards on Colombo city region fish supply including food security and nutrition. The climate hazards in the production regions translate into supply chain vulnerability and risk with impacts on production and postharvest losses along the chain; this is finally reflected in the Colombo retail price with implications for the nutritional status of the poorer segments in the city region.

Figure 53. Cascading effect of climate hazards on the Colombo city region fish supply chain

Source: Authors.

4.5 IMPACT OF COVID-19 ON THE COLOMBO CITY REGION FOOD SYSTEM

- The Covid-19 pandemic impacted the city region food system mainly due to the closure of Peliyagoda fish market and the Manning Market during both the first and the second waves.
- A significant proportion of Colombo city region inhabitants are vulnerable to shocks both in terms of climate change and the pandemic.
- Fish and coconut production dropped by 41% and 25% respectively during the first wave of the pandemic.
- The prices of rice, vegetables, coconut and fish were impacted by the pandemic.
- Rice prices increased during the second wave of the pandemic.
- Government intervention in terms of payment of a relief grant to vulnerable groups during both waves of the pandemic was an important step.
- The government also encouraged home gardening; as a result the local food system in the rural and peri-urban areas became active.

4.5.1 Status of Covid-19 in Sri Lanka

The first international Covid-19 patient was reported in Sri Lanka on 27 January 2020. However, the first local Covid-19 case was detected on 10 March 2020. On 14 March all government schools and universities were shut down to prevent the spread of the disease. By 23 March 2020, the Sri Lankan Army had set up 45 quarantine centres as a preventive measure to accommodate close contacts of infected people. An island-wide curfew was imposed on 20 March which continued with short breaks for purchasing essentials until 11 May. The lockdown-style curfew continued for 52 days during which measures were taken to deliver essential food items to homes with the participation of supermarket chains and retailers. Further, a Presidential Task Force was established to coordinate and strengthen food distribution, import essential food items, facilitate food production by farmers, and to give attention to low-income families and vulnerable groups.

The second Covid-19 wave began on 4 October with emergence of the Minuwangoda and Divulapitiya clusters. On 21 October with new cases reported at Peliyagoda fish market, it was shut down with immediate effect. On 25 October, a quarantine curfew was imposed in some areas of Colombo; this curfew was extended to the entire Western province from 29 October to 2 November.

The Colombo city region food system was affected by Covid-19 in many ways during the first and the second waves of the pandemic. The Peliyagoda fish market and the Manning Market were identified as hotspots for spread of the virus. The Peliyagoda fish market considered as the national wholesale fish market in Sri Lanka became one of the epicentres of Covid-19 infection with serious implications for distribution of fish in the Colombo city region. Several fishing harbour operations were curtailed due to detection of close contacts with the Peliyagoda fish market cluster.

The other major food distribution hub, the Manning Market, was closed in April and November 2020 and this also impacted food distribution in the Colombo city region as the Manning Market plays an important role in the distribution of food, especially vegetables, to the Colombo city region.

4.5.2 Exposure and vulnerabilities of the Colombo city region food system

A significant proportion of Colombo city region inhabitants was vulnerable to shocks because their livelihoods were dependent on daily wages earned from the informal sector. In Sri Lanka, informal workers account for 70% of the workforce. The dependency ratio is a good proxy indicator for the vulnerability of the population to the Covid-19 pandemic. The dependency ratio is the proportion of the population above 60 years and below 15 years to the population aged from 15 to 59. Figure 54 shows the GN divisions within Colombo DSD with higher dependency ratios. It is clear that a significant number of GN divisions have a higher dependency ratio implying a high vulnerability to the Covid-19 pandemic.

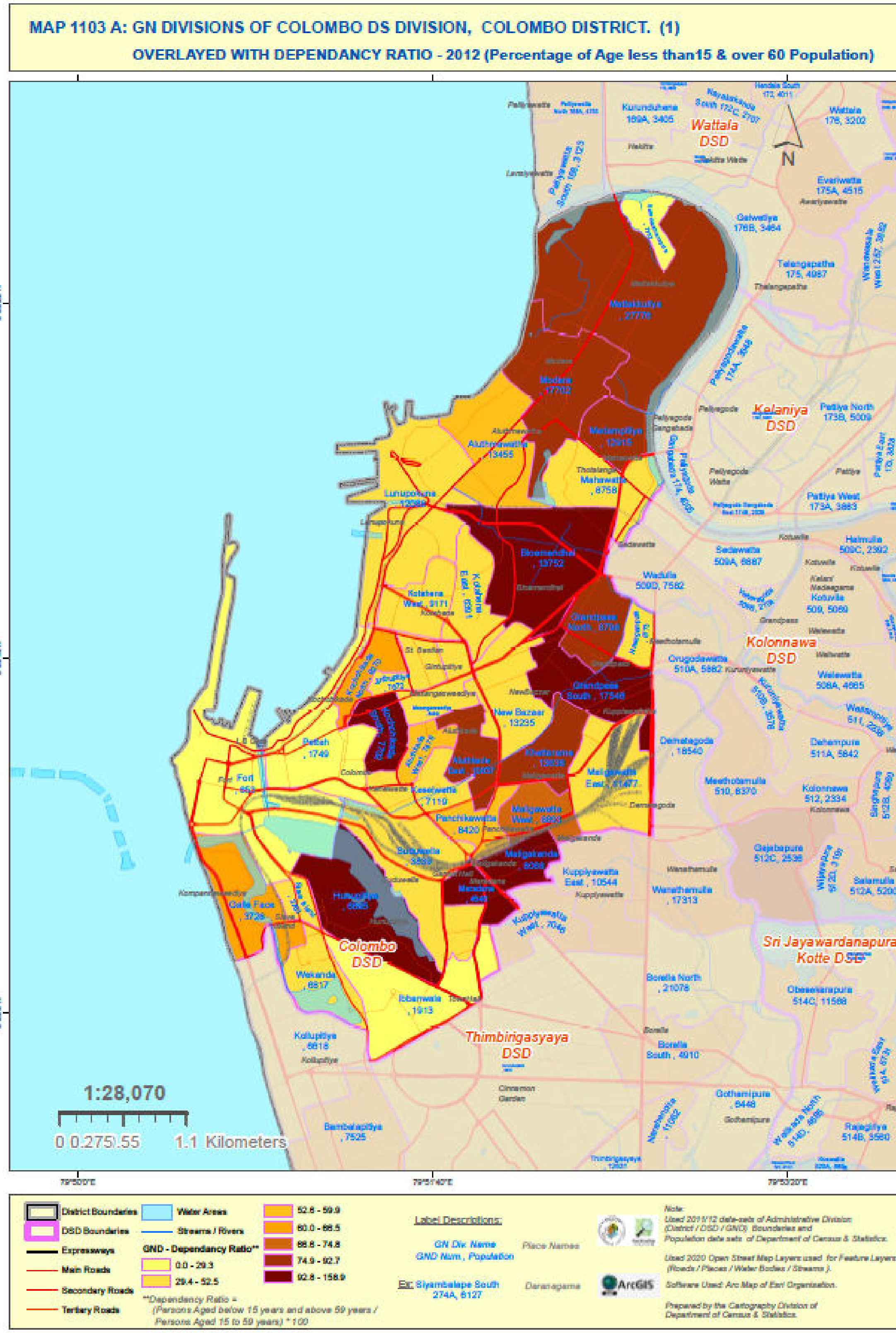


Figure 54. Colombo DSD map with dependency ratio

Source: DCS (2020).

4.5.3 Pre-existing and persistent nutritional challenges

A nutritional study of reproductive age women in marginalized areas of the Colombo city region revealed that knowledge, practice and attitudes of women affect BMI status and household food security (Weerasekara et al., 2020). Colombo District is known to have the highest proportion of food insecure population in the country (Mayadunne & Romeshun, 2013). According to Deyshappriya (2019), 59% of households in Colombo District are below the Minimum Dietary Energy Requirement (MDER). As a result of the pandemic, the poverty level at the national level is expected to increase from 8.9% to 13% implying that about 890,000 people are becoming new victims of poverty (Zervos, 2020).

As Colombo District is the most food insecure district in the country, this turn of events can have far reaching implications for food security and nutrition of the vulnerable groups. Child malnutrition is a serious public health concern in Sri Lanka (Naotunna et al., 2017). The three indicators used to assess child malnutrition namely stunting, wasting and being underweight are 15.6%, 11.9% and 14.6 respectively in Colombo District (DCS, 2017). Although these values are slightly lower than the national average, they are still serious public health concerns heightening the vulnerability of city region communities to multiple hazards.

4.5.4 Pre-existing climate change and extreme weather-based challenges

The Colombo city region is highly vulnerable to extreme weather events. From 2015 to 2020, 16 heavy rain and 15 flood events affected the Colombo city region with implications for food distribution and consumption. When Sri Lanka was hit by a strong cyclone in 2016 several parts of Colombo suburbs were flooded affecting food supplies (Urban Agriculture Magazine, 2018). Similarly, heavy rainfall in May 2018 resulted in flooding, forcing the evacuation of people in low-lying areas. Such conditions are likely to exacerbate the impacts of the pandemic on the city region food system.

4.5.5 Vulnerable, fragmented value chains and poor food system governance

The vulnerability of most of the supply chain became evident during the pandemic.

The closure of Dambulla DEC in April due to a curfew created a chaotic situation in the distribution of fruits and vegetables received at the DEC at a rate of around 5,000 tonnes to 10,000 tonnes/day (Eraminigammana, 2020). Imposition of a curfew in the Western province in early November and the closure of the Manning Market resulted in piling up of 2.7 million kg of vegetables in the Dambulla DEC destined for the Colombo city region (" Million kilos", 2020). In October, about 350,000 tonnes of fish were left unsold in the harbours of the Western fishing belt due to the closure of Peliyagoda fish market and consumer reluctance to consume fish for fear of Covid-19 infection from fish ("Corona spreads", 2020). There was a shortage of rice supplies in May following the government's imposition of a maximum retail price ("Islandwide rice shortage", 2020). Poor food system governance let a few players in the rice supply chain control the rice supplies and contributed to shortage of rice in the market.

4.5.6 Data gaps

The poor availability of data related to the impacts of Covid-19 on food supplies and distribution is a serious limitation in identifying vulnerabilities in the food system and making recommendations to build resilient food systems in times of crises such as the Covid-19 pandemic.

4.5.7 Food production and price fluctuation

According to Figure 55, both upcountry and low country vegetable prices have remained below the 2019 averages. The low country vegetable prices dropped sharply compared to the upcountry vegetable prices. The possible reasons are drop in demand by consumers, restaurants and hotels, disruption to supply channels, closure of the Manning Market and drop in farmgate prices. The impact of the pandemic was felt more seriously at the Dambulla DEC with more days of closure and disturbance to low country vegetable supply channels compared to the upcountry DECs such as Keppetipola and Nuwaraeliya and their supply channels.

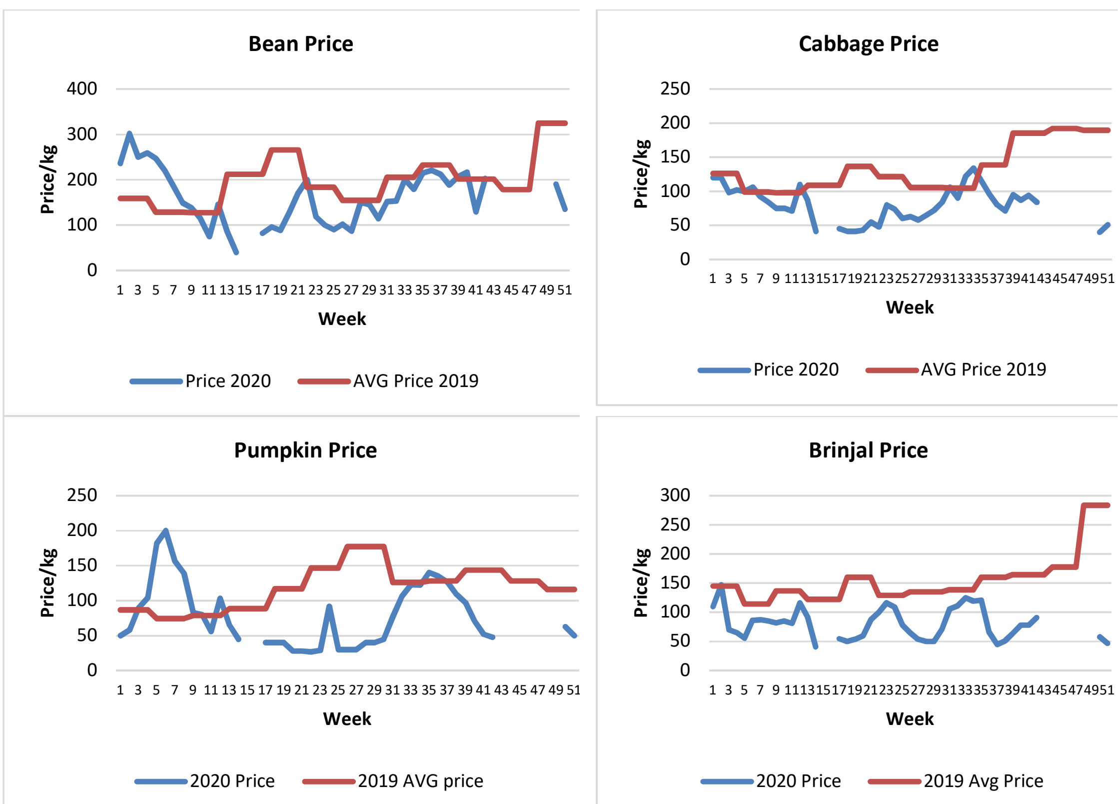


Figure 55. Vegetable price fluctuations in Colombo during the pandemic period

Note: The discontinuation of the scatter lines is due to lack of data.

Source: Compiled from CBSL weekly economic indicators, various weeks.

The rice prices at the initial stages of the pandemic remained below the average of the previous year (Figure 56). The imposition of a maximum retail price (MRP) in April did not have a significant effect on the retail prices although there were shortages of rice in the market. The MRP was revised upwards in May to manage the supply shortages. However, with emergence of the second wave in October, the prices went up due to issues in the governance of the rice supply chain. Further, because rice consumption seems to have increased as a result of reduction in the consumption of wheat flour and bakery products (Abeysinghe, 2020), this could have had a possible impact on rice prices.

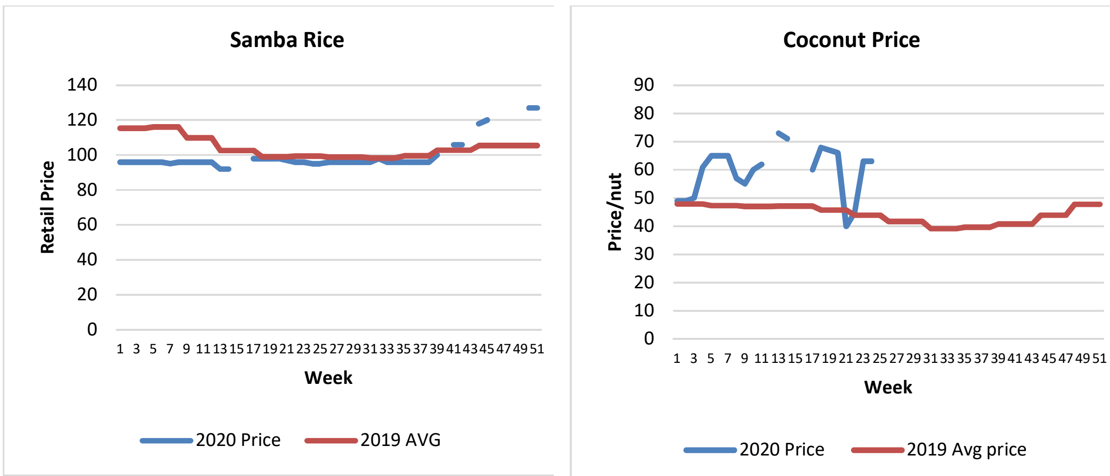


Figure 56. Rice and coconut price fluctuations in Colombo during the pandemic period

Note: The discontinuation of the scatter lines is due to lack of data.

Source: Compiled from CBSL weekly economic indicators, various weeks.

The impact of the pandemic significantly affected fish prices throughout 2020. The prices of sample fish types shown in Figure 57 are significantly below the average prices in 2019. This price drop can be attributed to the closure of Peliyagoda fish market and the perception of consumers that fish could spread Covid-19. As a result of the negative perception of fish and complete disruption of fish supplies to the Colombo city region fish consumption drastically dropped during both waves of the pandemic. The unsold fish was not sent for dry fish making because the dry fish industry did not operate due to Covid-19 restrictions; as a result there was significant wastage of fish (Amarasinghe & Piyasiri, 2020).

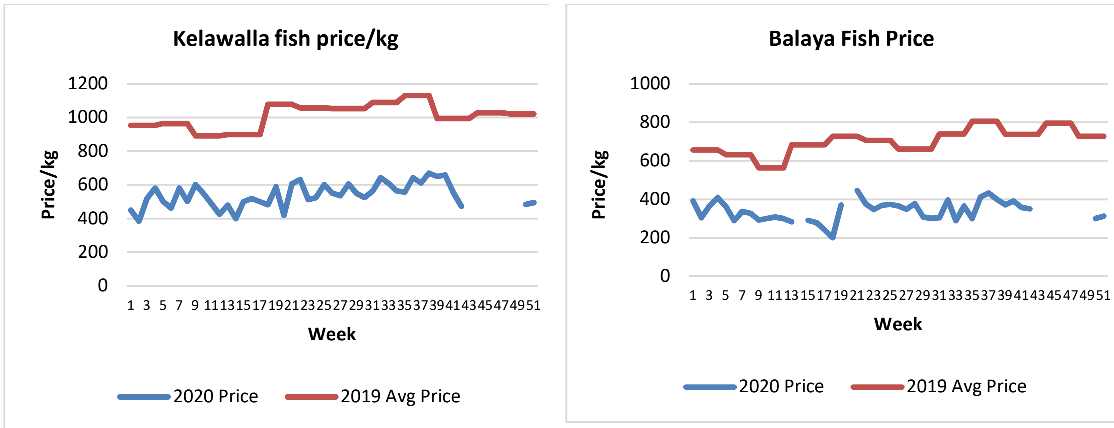


Figure 57. Fish price fluctuations in Colombo during the pandemic period

Note: The discontinuation of the scatter lines is due to lack of data.

Source: Compiled from CBSL weekly economic indicators, various weeks.

The drop in fish prices did not benefit consumers nor it had an impact on the nutritional profile of the consumer as consumption remained low as discussed above. Survey findings[1] reported that 81% of families did not have access to fish in April 2020. The impact of Covid-19 on fish production was very significant especially in the first wave and second wave. Production dropped by more than 40% compared to the previous year in April and May (Figure 58). The drop can be attributed to the restrictions imposed on fishing and closure of fishing harbours and the Peliyagoda fish market in Colombo. The situation gradually returned to normalcy from July and by August production was almost normal. However, this only lasted for one month as the second wave emerged and infected people were detected in the Peliyagoda fish market. The disease spread to main fishing harbours with consequential drop in production from October to December. Peliyagoda fish market was shut down from October to December 2020.

[1]Impact of COVID-19: Health Emergency Rapid Assessment, World Vision Sri Lanka; telephone survey conducted from 17-20 April, 2020.

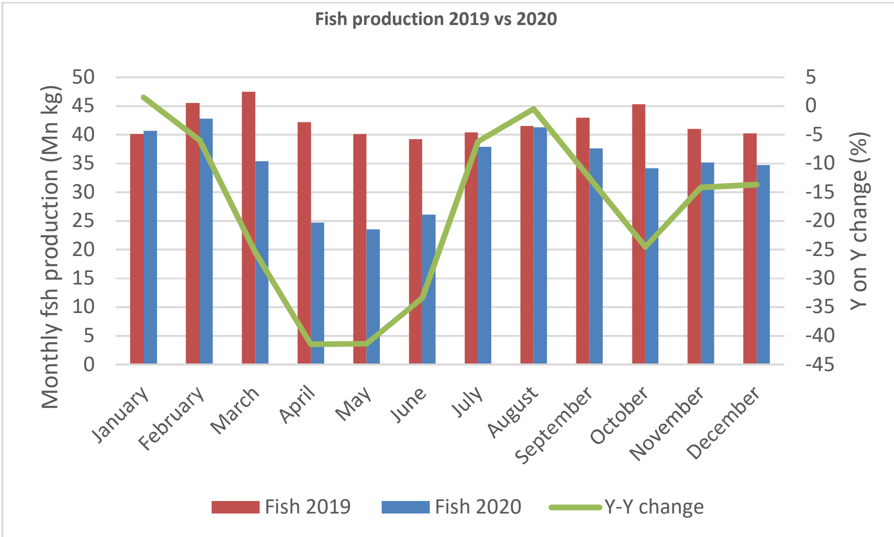


Figure 58. Fish production fluctuations during the pandemic period

Source: Compiled from CBSL monthly economic indicators, various months.

Coconut production showed an approximate 25% decline in March and April 2020 compared to the same months in 2019 (Figure 59). This could be partially attributed to the seasonality and issues with mobilizing labour to harvest coconut due to the pandemic. Generally, coconut prices were comparatively high during the pandemic period due to supply drop and disruption to the coconut supply chain.

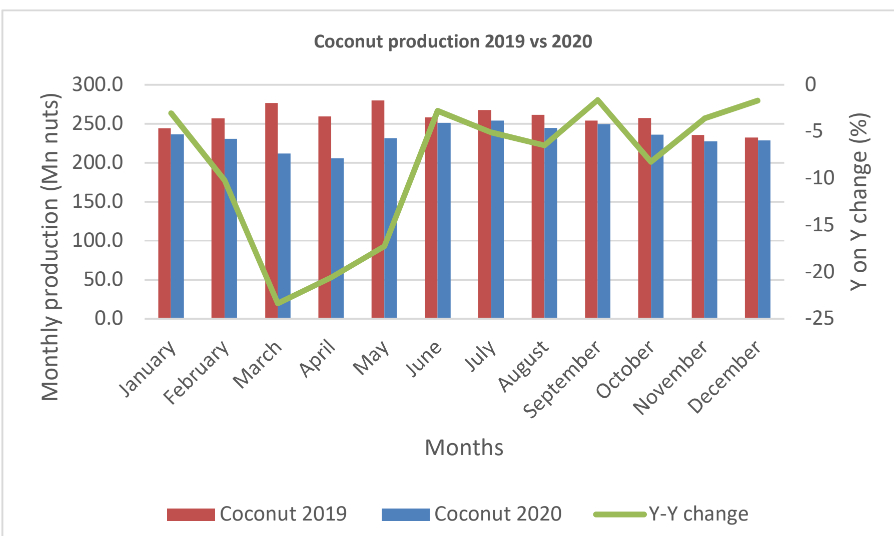


Figure 59. Coconut production fluctuations during the pandemic period

Source: Compiled from CBSL monthly economic indicators, various months.

Table 44 summarizes the impact of Covid-19 on national food production, distribution and prices which have clear linkages to the foregoing discussion on the Colombo city region food system.

Table 44. Summary of impact of Covid-19 on supply chains from January to August 2020

Coconut	Paddy rice	Fish	Vegetables
• Total production declined by 11.3 % compared to the same period in 2019. • Decline can be attributed to the combined effect of the extended effect of dry weather conditions that prevailed during mid-2019 and disturbances related to the COVID-19 pandemic. • Coconut oil declined by 60.4% due to factory closures and mobility restrictions of the COVID-19 outbreak. • The supply shortfall resulted in a sharp increase in prices of coconut and coconut-based products. • The average retail price of a coconut increased by 39.4% to LKR 70.20 per nut compared to the same period of 2019.	• 2019/2020 Maha production increased by 4.0% to 3.2 million tonnes in comparison to the previous Maha season due to favourable weather. • Paddy prices remain high despite sufficient production due to competition among mill owners to purchase paddy. • Average retail price of Nadu rice increased by 9.4%, average retail price of Samba rice declined by 1.2% compared to the same period in 2019.	• Production declined by 15.7% to 283,485 tonnes with marine fish production declining by 20.2% due to mobility restrictions and adverse weather conditions. • Considerable wastage took place due to fish market closures during the lockdown period. • The demand for fish dropped considerably during the lockdown period; as a result the fish prices dropped. • Closure of hotels and restaurants and the drop in tourism sector hampered the fisheries sector.	• Production during the 2019/2020 Maha recorded an increase of 7.0%, year-on-year, to 893,930 tonnes. • This can be attributed to the combined effect of favourable weather and prices. • COVID-19 related lockdowns affected interseasonal cultivation in March and April.

Source: Recent Economic Developments, Central Bank of Sri Lanka (2020).

4.5.8 Impact of Covid-19 on supermarket chains

The major supermarket chains reported issues with cross-border transportation of vegetables from production regions to Colombo city regions despite the government relaxing restrictions to transport food items during the curfew and lockdowns. Both major supermarket chains indicated production was not affected but procurements were affected due to the restrictions. Customer visits to outlets were significantly affected during the first wave but not during the second wave. Even though customer visits dropped, since the purchasing volume of individual customers was high, overall sales were not affected much. Both chains reported panic buying of food items; as a result some food items were in short supply with implications for poorer segments who could not afford bulk purchasing. According to the supermarket chains, although the government swiftly intervened in the first wave to facilitate food distribution, there were issues at the ground level in implementation of the directives and flow of reliable information about the unfolding pandemic. Both supermarket chains effectively utilized their online platforms to facilitate home delivery, which received overwhelming demand during the curfew and lockdown periods.

4.5.9 Recovery and resilience

The government provided a grant of LKR 5,000 during the initial lockdown in March 2020 to about four million Sri Lankans who made up the vulnerable population, including 416,764 senior citizens, 119,300 people with disabilities, 160,675 farmers who were registered under the Farmers' Insurance Scheme, 39,170 kidney patients and 2,443,844 Samurdhi recipients to enhance household resilience to the pandemic ("Rs. 5000 each", 2020). During the second wave in October, the government allocated LKR 400 million to distribute LKR 5,000 each to those who had lost their livelihoods due to curfews in particular districts. Private companies, media institutions, social organizations, voluntary groups and organizations distributed dry rations and vegetables to needy people to support their families.

Recovery and resilience of vulnerable communities were enhanced through various initiatives taken by the government. Some of them are summarized in Table 45.

Table 45. Measures taken to manage the food supply chain

Timeline	Key measures taken to manage the food supply chain	Source
March 16	A relief package to support people affected by COVID-19, MRP for red lentil and canned goods implemented through the State Retail Chain (Lak Sathosa).	(Gazette Extraordinary No. 2167/9) – Consumer Affairs Authority/, Weerahewa et al. (2020)
March 18	MRP of lentils reduced to LKR 65/kg MRP of big onions reduced to LKR 150/kg MRP of canned fish reduced to LKR 100/450g	"Recent economic developments" (2021) 2021)
March 23	Sri Lanka Ports, Customs and other regulatory bodies were requested to continually issue essential food, fertilizer, etc.	Weerahewa et al. (2020)
March 24	Instructions issued to refrain from closing down stores until the last customer in the queue was able to purchase goods.	Weerahewa et al. (2020)
March 25	A special mechanism was established to deliver essential food items to homes in collaboration with cooperatives and retailers.	Weerahewa et al. (2020)
March 25	Facilitate cultivation of vegetables, paddy, maize, black gram, green gram, cowpea and finger millet, and fisheries activities without any interruption even during curfew time.	Marambe & Silva (2020)
March 26	The Presidential Task Force set up a coordination mechanism to import essential dry food items, facilitate farmers for the production of rice, grams, vegetables, fish, dairy and eggs, give particular attention to women, low-income families and vulnerable persons, and distribute rice, vegetables and other products to the people of all districts.	Weerahewa et al. (2020)
March 28	Facilitation of food and essential goods transport during the curfew period. This included vegetables, fruits and coconuts transportation to all economic centres and the Manning Market.	"PM instructs IGP", (2020)
March 30	Circular issued to provide essential food items at concessionary rates to low income and vulnerable families/persons as well as allowances.	Marambe & Silva (2020)
April 4	The Saubhagya National Programme on harvesting and cultivation was launched to develop 1 million home gardens.	"State initiative", (2020)
April 9	Sri Lanka's coconut auction was launched online.	Jayasinghe (2020)

April 9	The government allocated LKR 600 million for the purchase of the fish harvest.	Perera (2020)
April 10	MRP imposed for selected rice varieties, e.g. Keeri samba LKR 125/kg; Suduru samba LKR 90/kg The services of rice mill owners were declared an essential service. The special commodity levy on palm oil was increased.	"Rice mills declared", (2020) Farzan (2020)
April 11 & 14	The government procured vegetables and fruit stocks from farmers via the 120 divisional secretariat divisions.	"Govt. to purchase", (2020)
April 15	Sri Lanka Railway to deploy special trains to transport vegetables fruits, grains, rice and other essential commodities cultivated from various parts of the country to ensure availability of these products during the curfew.	Marambe & Silva (2020)
April 17	A concessionary loan scheme for farmers was launched.	Weerahewa et al. (2020)
April 20	The government allocated LKR 20 million to purchase unsold fish from the Mirrissa harbour in Matara District	"Rs. 20 million", 2020)
April 22	Closure of Manning Market.	" Closure of Manning", (2020)
April 23	The government set guaranteed prices on 14 crops and undertook to procure harvest if farmers were unable to sell at guaranteed prices.	"Guaranteed price", (2020)
April 30	*MRP of lentils and canned fish removed.	"Recent economic developments", (2021)
April 30	Allocation was made to import 150,000 tonnes of fertilizer. Encouraged the cultivation of 16 additional crops for which the government provided a guaranteed price. Established 200 specialized agriculture cluster villages. Established 50 green gardens and 200 harvest selling outlets.	Marambe & Silva (2020)
May 11	A special mechanism was formulated for those who arriving in Colombo, crossing district boundaries for essential services.	"Planned to restore", (2020)
May 11	Removal of official lockdown.	Marambe & Silva (2020)
May 21	The government filed legal action against 780 rice retailers for violating the MRP ceiling.	" Island wide rice shortage", (2020)
May 28	*MRP of white/red samba, steamed/boiled samba increased.	"Recent economic developments", (2021)
May 28	The government imposed minimum support prices for 14 subsidiary food crops including green gram, cowpea, black gram, onion, maize and potatoes.	Vidanapathirana (2020)
September 25	Setting MRP for coconuts based on circumference.	"Recent economic developments", (2021)
October 20	Hotels and restaurants were shut down in Colombo, steps were taken by them to use food delivery services to deliver food to residents.	"Corona spreads", (2020)
October 25	Increasing public awareness on fish consumption (no Covid-19 infection).	Jayamanna (2020)
November 11	Closure of Manning Market	"Pettah Manning public", (2020)

The local food systems in rural and peri-urban regions became active during the pandemic as home gardening and local food production received renewed attention. The residents spent more time on home gardening and cultivating fallow land during the lockdown and curfew periods. A survey[2] conducted in the peri-urban area revealed that home gardeners shared surplus produce from their home gardens with neighbours and the community. Increased engagement of women in home gardening and food production was also revealed. Government intervention through the Saubhagya national programme was implemented to promote 1 million home gardens with seeds and plants being distributed among home gardeners; this also contributed to the food production drive in local communities, especially in urban areas.

4.5.10 Emergence of alternate food supply chains

The pandemic period led to the emergence of alternate food supply chains including self-organizing food distribution systems, e-commerce platforms and social media (Figure 60). Leading supermarket chains expanded their online platforms to cater to increasing demand during the lockdown and curfew periods. Local government authorities and local cooperatives-initiated delivery services of essential commodity packs at affordable prices. Three-wheelers and small trucks were mobilized to deliver essential food items including fish, vegetables and provisions to doorsteps and local areas. Taxi service providers such as Pickme and Uber delivered essential supplies to households in Colombo and the suburbs. The local authorities encouraged street vendors to sell their produce on roadsides and less congested areas to prevent people from flocking to traditional markets when lockdowns were relaxed.

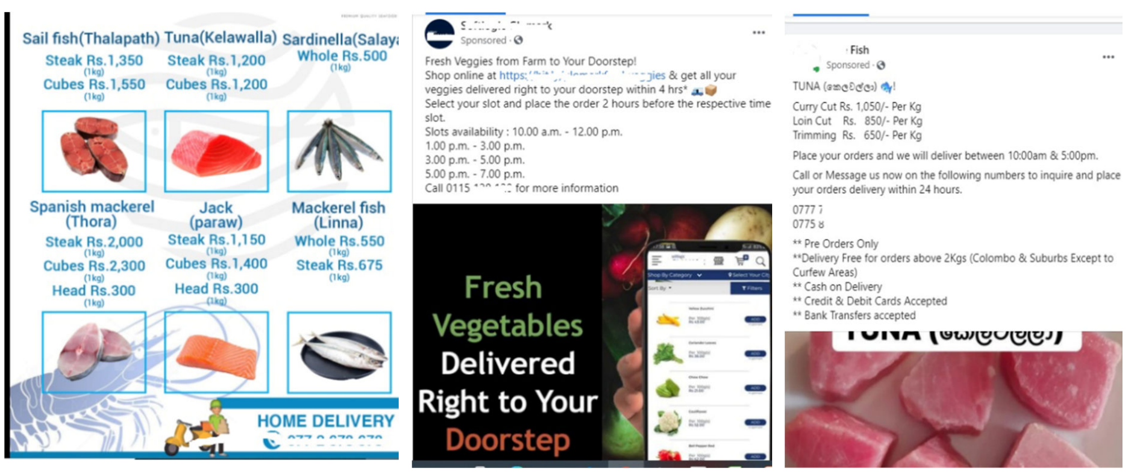


Figure 60. Examples of alternate food supply channels based on e-commerce platforms and social media

Source: Social Media

[2]Dominish, E., Hettiarachchi, K., Samarkoon, D., Esham, M., Winterford, K. and Jacobs, B. (2020). *Social and market research on organic waste value chains in Sri Lanka.* Report prepared by the Institute for Sustainable Futures at the University of Technology Sydney, Janathakshan (GTE) Ltd and Sabaragamuwa University of Sri Lanka.

Figure 61 shows the impact of Covid-19 on the Colombo city region food system. Curfew, lockdowns and mobility restrictions affected the livelihoods of people especially those in the informal sector earning a daily wage; on the supply side, mainly supply chain disruptions and to some extent production disruption, led to poor availability and accessibility to food. In the early stages of the pandemic, panic buying was prevalent; as a result some food items such as rice, vegetables, coconuts were in short supply. Due to the disruption to supply chains many alternative supply channels involving both private and public sectors emerged. Of these channels, home delivery using three-wheelers and small trucks was carried out by those who lost their earning opportunities in the informal sector such as three-wheeler taxi operators, construction workers, etc. There were very effective government interventions such as LKR 5,000 relief payments for the needy during the first wave of the pandemic. However, the interventions were not so effective during the second wave.

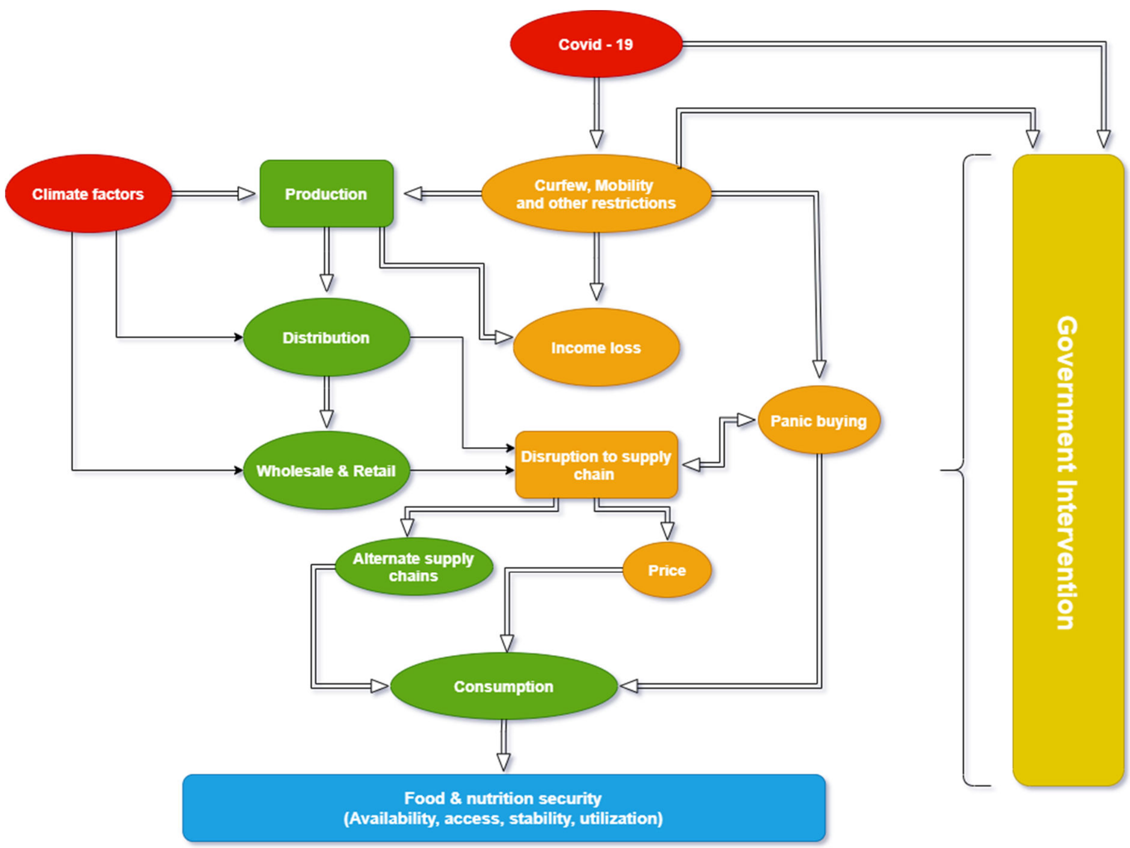


Figure 61. Impact pathways of Covid-19 on the Colombo city region food system

Source: Authors.

4.6 FOOD SYSTEM GOVERNANCE WITH REFERENCE TO THE COLOMBO CITY REGION FOOD SYSTEM

- The CCS has developed a number of policies, strategies and plans to govern climate change challenges in Sri Lanka but action suffers from inertia.
- Inefficiencies have been identified in the early warning systems due to poor resource allocation and lack of coherence and integration of the system.
- The agricultural insurance sector is far behind in terms of the climate challenges posed to the agricultural sector. The introduction of innovative insurance schemes is essential.
- The complex multilevel governance structure in place to address climate change issues creates many challenges to coordinate and integrate a diverse set of institutions entrusted with the responsibilities at different scales viz., national, provincial, district and local.

The governance of the Colombo city region food system will be discussed from a national perspective giving emphasis to agriculture policy, climate change, early warning and farmer insurance. Refer to Marambe et al. (2020) for a detailed description on institutional coordination mechanisms, policies, strategies and action plans related to Colombo city region food systems.

4.6.1 Agriculture policy

Agriculture in Sri Lanka is covered by national policies and sectoral policies. There are many sectoral policies covering agriculture. The latest is the overarching agriculture policy formulated by the Ministry of Agriculture along with other relevant ministries. The overarching agriculture policy document identifies five core areas for strategic policy action such as increasing productivity of farming; energizing domestic farm-market linkages and the rural economy; increasing export earnings; mainstreaming gender and youth; and implementing effective mechanisms to coordinate, guide and monitor sector development. In this policy document, ten thematic areas are covered among the themes of food security, water management, climate change, food security and effective governance that have direct relevance to building resilient food systems. A notable deviation from other agricultural policy documents is the prominence given to effective governance. Poor governance is known to be an underlying cause for the failure of many policies due to the lack of a coordination and monitoring mechanism of many entities at multiple scales involved in implementing policy actions.

4.6.2 Climate change governance

To facilitate effective climate change adaptation, an effective and efficient governance structure is indispensable. Most of the national climate change policies, strategies and action plans along with the governance and institutional set ups have direct relevance to the city region food system. Therefore, the ensuing discussion on the city region's climate change governance covers national-level interventions to address climate change challenges.

The National Environmental Action Plan (NEAP) was the first government initiative in 1992 to consider climate-related issues, along with environmental issues, and proposed recommendations to mitigate them (NEAP, 1991). In Sri Lanka, climate change policies have evolved over time with many initiatives. Ratification of the United Nations Framework Convention on Climate Change (UNFCC) in 1993 was an important milestone of the long journey. Establishment of the Climate Change Secretariat (CCS) in 2008 was notable initiative. The Ministry of Environment as the national focal point for the UNFCCC and Kyoto Protocol entrusted responsibilities to the CCS to address climate change challenges. The CCS has devised a number of policies, strategies and plans to govern climate change challenges in Sri Lanka. Among them the 'National Climate Change Adaptation Strategy (NCCAS) for Sri Lanka 2011 to 2016', the 'National Climate Change Policy (NCCP) of Sri Lanka' issued in 2012 and the 'National Adaptation Plan (NAP) for Climate Change Impacts in Sri Lanka' issued in 2016.

The NCCAS spelled out a prioritized framework of action for building climate change resilience in Sri Lanka from 2011 to 2016. It identified five strategic thrusts areas under which key thematic areas for action and priority adaptation measures were outlined. The thrust areas included: 1. Mainstream climate change adaptation into national planning and development; 2. Enable climate resilient and healthy human settlements; 3. Minimize climate change impacts on food security; 4. Improve climate resilience of key economic drivers; 5. Safeguard natural resources and biodiversity from climate change impacts. It was envisaged that an estimated LKR 47.7 billion would be required to implement the actions. The third thrust area had direct relevance to food security and food systems. It focused on an integrated approach to minimize climate change impacts on food security and build resilience to climate change risks covering areas such as irrigation, agriculture, fisheries, nutrition and environment sectors. Four thematic areas were identified including: ensuring ability to meet food production and nutrition demand; ensuring adequate water availability for agriculture; mitigating food security-related socio-economic impacts; and increasing awareness and mobilizing communities for climate change adaptation.

The NCCP of Sri Lanka came into effect in January 2012. The long-term goal was to provide policy guidelines to minimize impacts from climate change. The document contained six thematic areas: vulnerability, adaptation, mitigation, sustainable consumption and production, knowledge management and general statements. There were 25 broad policy statements under the six thematic areas. Of these broad policy statements many covered agriculture, food production and food security-related aspects. This document placed emphasis on the need for coordination among institutions at all levels including national and subnational levels.

The NAP for climate change impacts in Sri Lanka for the period 2016 to 2025 was initiated in 2013 to take forward the policy objectives of the NCCP. The aims of the NAP were to build adaptive capacity of individuals, communities and society to cope with the impacts of climate change effectively; reduce vulnerability to climate risks by enhancing the resilience of communities and ecosystems; and capturing any opportunities due to changes for maximum gain for society.

The NAP focused on nine key sectors and priority areas: food security, water resources, coastal and marine sector, health, human settlement and infrastructure, ecosystems and biodiversity, tourism and recreation, export agriculture sector and development and industry, energy and transportation. Further, the NAP identified ten cross-cutting areas of national issues and areas of interest namely, policy, legal, economic and governance issues, institutional development and coordination, international cooperation and partnerships, resource mobilization, research and development, technology development and standards, building of adaptive capacity of communities, education, training and awareness, climate-induced disaster risk management and climate information management. Food security including agriculture, fisheries and livestock was a key vulnerable area identified in the NAP.

The NAP specifies sectoral action plans. Adaptation actions are proposed for the identified nine vulnerable sectors. There are various priority adaptation actions proposed for agriculture and food security-related sectors (Appendix IV).

4.6.3 Provincial climate change adaptation

At the provincial level, the Western province has come up with a climate action plan in line with the NAP. The Action Plan spells actions for better information sharing and networking to support adaptation to climate change in the province. The provincial climate change action plans have not been effectively implemented due to incompatibilities with other national plans and lack of a clear legal mandate for provincial councils to act on climate issues (Pallawala, 2018).

Appendix V shows the budgetary allocations and donor financing for facilitating climate change-related initiatives for the period 2008 to 2017.

4.6.4 Early warning systems

The National Disaster Management Centre (NDMC) is the agency responsible for coordinating early warning with the support of relevant technical agencies and technical committees. The Emergency Operations Centre of the DMC is responsible for coordinating with technical agencies responsible for natural and man-made hazards. It will take steps to inform the officers responsible for onward communication to the subnational levels and communities. Appendix VI shows the Early Warning Dissemination System and the respective agencies involved in the Multi Hazard Early Warning (MHEW) system.

Communication of early warnings originating from local and international technical agencies goes through four layers namely, national, district, divisional and village levels. The vulnerable communities receive warnings through local authorities. Grama Niladhari’s local police, CBOs, NGOs, the military, and volunteers are involved in dissemination activities at the local level. The policy and legislation related to the disaster management framework are summarized in Appendix VII.

Considerable inefficiencies have been identified in government response, resource allocation and coherence and integration of the system (Siriwardana et al., 2018). Research results revealed that early warning communication mechanisms were poor and as a result the recipients had less trust and showed reluctance to respond to early warnings (Perera et al., 2020). Discussions with supermarket stakeholders revealed that they do not factor early warnings into their supply chain decisions. Farmers and intermediaries too have less trust in early warnings and use them sparingly in their decision-making. Improvements are being proposed for communication channels through the introduction of a better nationwide emergency communication system to directly disseminate warnings to vulnerable communities using advanced technologies (Hippola et al., 2018). Community Based Early Warning Systems (CBEWS) and upgrading last mile communication tools using the social media are some other ways to improve the system (Perera et al., 2020).

4.6.5 Agriculture insurance

With climate impacts on agriculture becoming apparent, the importance of agriculture insurance schemes has emerged as an important risk management strategy to protect the livelihoods of farmers and fishermen. The Agriculture and Agrarian Insurance Board (AAIB) is the national agriculture insurer in Sri Lanka. It was established under the Agricultural and Agrarian Insurance Act, No. 20 of 1999 and is responsible for undertaking the government crop insurance scheme. According to the Agricultural Insurance Law although paddy insurance is compulsory, subscription is voluntary, thus farmer participation remains at around 10% (Prasada, 2020). Figure 62 shows the evolution of climate insurance in Sri Lanka from 1958 to 2018. Some initiatives have been taken to transform the system from indemnity-based insurance to indexed-based insurance.

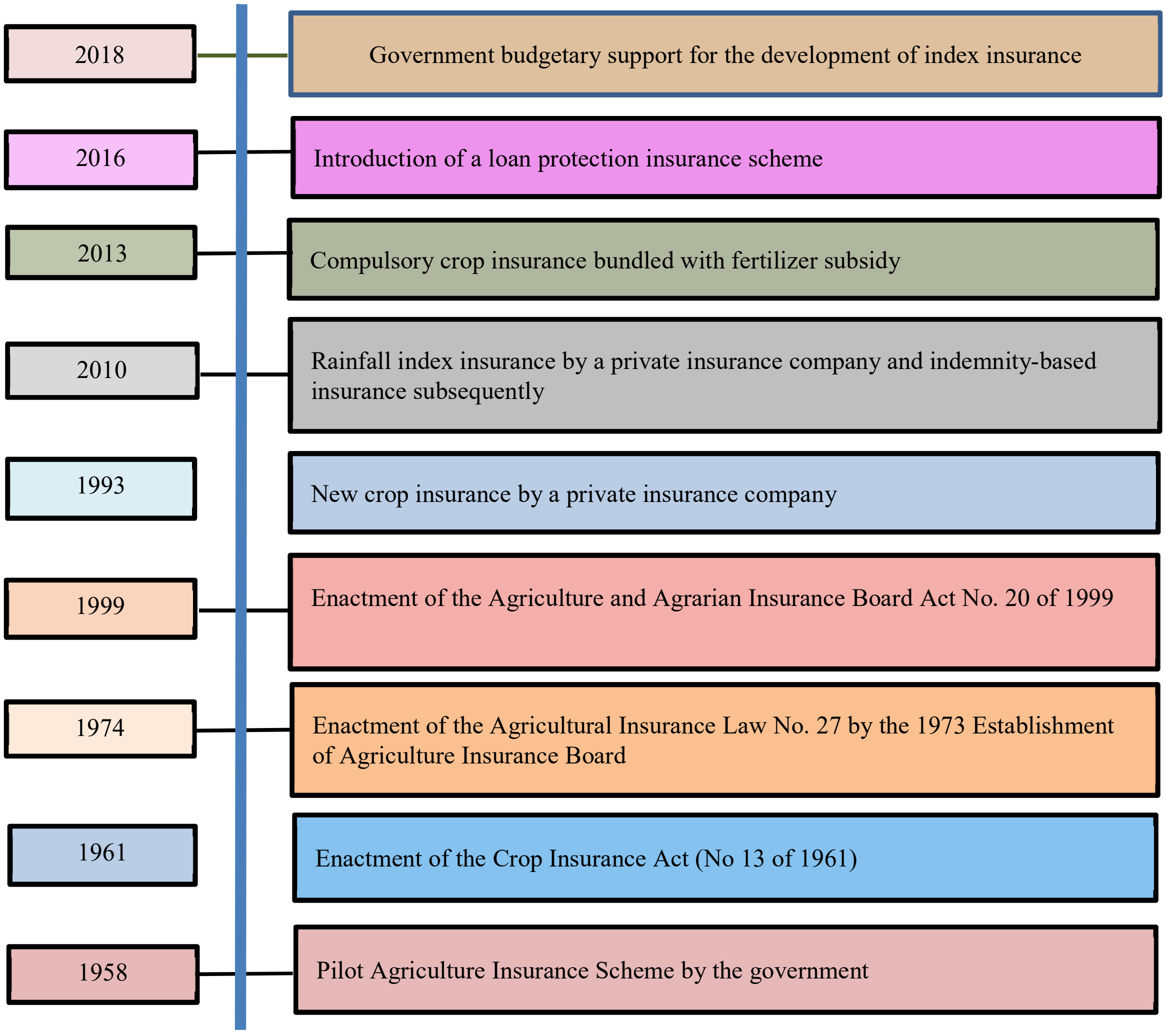


Figure 62. Timeline of climate insurance in Sri Lanka

Source: Wickramasinghe (2019).

There are several entities including public sector, profit and non-profit organizations involved in the agricultural insurance sector as shown in Table 46.

Table 46. Entities responsible for farmer insurance

Public sector	**Private sector**	**Non-profit organizations**
Agricultural and Agrarian Insurance Board	Ceylinco Insurance Company Ltd.	Oxfam International
Farmer's Trust Fund	SANASA Insurance Company Ltd.	
National Insurance Trust Fund	Others: Ceylinco House, Co-operative Insurance Company Limited, Softlogic Life, Insurance PLC, LOLC General Insurance Limited,	

	HNB Insurance, and Continental Insurance Lanka Limited.	

Sources: Wijenayake et al. (2019); "Blockchain crop", (2019).

The agricultural insurance uptake has remained very low except when the crop insurance was bundled with the fertilizer subsidy in 2013. Because it was compulsory the extent of areas insured reached 72% and 90% during the Maha and Yala seasons in 2015 (Wickramasinghe, 2019).

The AAIB provides indemnity-based crop insurance for rice, vegetables, other field crops and plantation crops. Farmer uptake of crop insurance is poor in Sri Lanka. A survey of 750 farmers, conducted in Anuradhapura District revealed that demand for crop insurance was extremely low. A significant number of farmers were not aware of the benefits of crop insurance (Wickramasinghe, 2019). Poor demand for crop insurance can be attributed to lack of awareness and trust in insurance products and reluctance to adhere to cumbersome insurance procedures (De Costa, 2020). For fishermen, the *Divi Saura* life insurance scheme was launched by the Department of Fisheries and Aquatic Resources in collaboration with Ceylinco Insurance to cover all life accidents.

Innovative insurance schemes are emerging with some being piloted in Sri Lanka. SANASA insurance in partnership with GIZ GmbH launched a weather-indexed insurance product for the first time in Sri Lanka based on an online platform ("Sri Lanka- SANASA", 2019). The block chain micro insurance scheme is piloted with paddy farmers by Oxfam International in Sri Lanka. It is an automated system and in the event of extreme weather, the claims are triggered automatically ("Blockchain crop", 2019).

Farmers have lost trust in traditional indemnity-based insurance in Sri Lanka due to lapses in damage assessment and lack of prompt compensation payment. Research has shown that farmers have understood the merits of weather-indexed insurance, thus there is potential provided that it is appropriately targeted (Prasada, 2020).

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 PADDY RICE SUPPLY CHAIN

The analysis revealed that drought is the major climate hazard that has impacted paddy production in the major production regions in the country. Of the six-year period under analysis, the hazard score was highest in 2017 and it shows a clear link to a drop in paddy production prompting import of a significant volume of rice to the country.

Anuradhapura District is relatively more vulnerable and carries higher risk among the three main paddy-producing districts in Sri Lanka as it has a comparatively higher proportion of paddy lands that are dependent on minor irrigation. Temperature is another important climatic parameter likely to impact rice production. However, the analysis does not provide any evidence that temperature has contributed to yield reduction.

The short supply of paddy due to climate hazards affects the milling industry. When the paddy supply drops there are instances where 50% to 60% of medium- and small-scale millers lack adequate supplies to continue their operations. The paddy marketing board has little influence in a market dominated by a few large millers with implication for rice availability and price.

The climate impact on paddy production is directly reflected in the Colombo retail price of rice. The price hike in Colombo matched low national production in both Maha and Yala seasons in 2017. Although in response to low national production a substantial quantity of rice was imported to the country, the prices have not come down to ease the burden on the consumer. The possible reason could be the time lag of the imported rice reaching the market. The high price fluctuation mainly due to climate hazards will have implications for affordability and dietary energy intake of poorer segments in the Colombo city region as it has the most food insecure population in the country.

Recommendations for building resilient paddy-rice supply chains

- The clear link between climate hazards and paddy production implies that climate change adaptation efforts need to be intensified and go beyond incremental adaptation to transformational adaptation.
- The paddy marketing board has to play a much bigger role to intervene to stabilize the rice market.
- There is a serious institutional fragmentation and disconnect among public and private sector stakeholders in the rice sector. e.g. data gaps. Therefore, it is necessary to develop a coordination mechanism involving relevant stakeholders from the public and private sectors such as the MoA, PMB, MoI, Department of Meteorology, DCS, rice importers,

large millers and wholesalers to continuously monitor the activities along the supply chain.

- Government intervention is needed to maintain rice buffer stocks to meet shortfalls in paddy production because climate change is likely to intensify in the future with more frequent weather extremes affecting production and other supply chain activities.
- The leakages of rice from the supply chain for purposes other than consumption need to be examined as there is a noteworthy number of reports in the media of confiscating significant amounts of spoiled rice stocks.

5.2 UPCOUNTRY AND LOW COUNTRY VEGETABLES

Most upcountry vegetables are supplied to the Colombo city region from Nuwara Eliya and Badulla districts. The major climate hazards are wind, landslides, floods and heavy rains. The major climatic hazard experienced by the low country vegetable-producing district, Anuradhapura, is drought. Hazard intensities in Nuwara Eliya and Badulla are moderate as wind is the most prevalent hazard.

Nuwara Eliya and Badulla districts are highly vulnerable to wind events seriously affecting vegetable production. In Anuradhapura District, the vulnerability is moderate, and the risk intensity is low due to availability of water for cultivation of low country vegetables as well as presence of dug wells and adoption of reasonable climate change adaptation practices.

The high-risk propensity of the upcountry vegetable supply chain implies that the impact of climate hazards, especially wind, can quickly move along the supply chain to the consumer in terms of significant price hikes. However, as far as low country vegetable supply chains are concerned, climate impacts are not translated into retail price hikes at the same magnitude as upcountry vegetables.

At the intermediary nodes of the supply chain, heavy rain and wind were the main hazards affecting operations of upcountry DECs including Keppetipola and Nuwara Eliya. Climate hazards are responsible for spoilage of vegetables at DECs as well in transportation. Early warning and climate forecasts are not considered seriously by the wholesalers and commission agents at the DECs in their decision-making. The DECs based traditional vegetable supply chains are responsible for about 85% of vegetable supplies to the Colombo city region.

Supermarkets play an important role as intermediaries in the supply of vegetables to the Colombo city region. The two leading supermarket chains in the country collectively hold about 10% of the market share in the supply of vegetables to Colombo city region. Both supermarket chains reported that losses during transport due to extreme weather were negligible as transportation was done in cold trucks. None of the chains reported using early warning systems and information related to weather in their procurement decisions.

There is no strong evidence to support the relationship between rainfall and retail prices of upcountry vegetables except for a few vegetable types such as leeks. However, according to farmers and intermediaries, wind was identified as the major climate hazard that could have a strong relationship with retail price escalation. This warrants further investigation. However, low country vegetable prices show some relationship with the rainfall pattern in production regions.

The current low consumption of vegetables can be attributed to the seasonal price fluctuation and the low purchasing power of the poorer segments of the population. The current consumption should go up by at least four to five fold to reach the recommended level of intake. However, with the prevailing prices of vegetables and price volatility it is unlikely that the poorer segments in the Colombo city region will be able to afford sufficient quantities of vegetables to have a balanced diet.
Climate impacts along the supply chains of vegetables are not quantified due to lack of data. Based on findings, it is reasonable to conclude that the impact of climate hazards on production and excessive postharvest losses along the supply chain are the main reasons for unaffordability of vegetables among the poorer segments in the Colombo city region. Climate change has also led to food safety concerns as excessive and erratic rainfall has prompted upcountry vegetable farmers to use excessive agrochemicals such as fungicides and pesticides with possible agrochemical contaminants in the vegetables reaching the markets.

Recommendations for building resilient upcountry and low country vegetable supply chains

- As both upcountry and low country vegetable producers and supply chain stakeholders are impacted by climate change, effective adaptation measures along the supply chain become imperative.
- Investments for infrastructure such as cold chain facilities, storage space, other basic amenities and capacity development at DECs are essential.
- It is necessary to develop a decision support system to match the demand and supply of vegetables to the Colombo city region on a daily basis.
- Vertical integration of farmers to mainstream supply chains through a network of collection centres and investment in supply chain infrastructure will help to build supply chain resilience.
- There are food safety and quality issues which at each node of the supply chain need to be addressed by the adoption of modern technologies and practices such as good agricultural practices.
- Studies are needed to understand the relationship between indiscriminate agrochemical usage and climate extremes, especially in the upcountry districts.
- Both the upstream (farmer end) and the downstream (consumer end) of the vegetable supply chain are relatively more vulnerable to climate hazards. Therefore, policy actions should focus on strengthening the resilience of vegetable farmers and protecting consumers by containing price volatility and escalation.

5.3 COCONUT SUPPLY CHAIN

Coconut production in the current year is highly dependent on the rainfall pattern of the previous year. The rainfall during February, June, July, September and December in the preceding year to the harvest is critical for the following years' production. Wind is the common hazard affecting coconut production in the coconut triangle. Drought is prominent in

Kurunegala and Puttlam districts. It can be inferred that drought-wind combined moisture stress is the major climatic factor contributing to production drop in the coconut triangle. Kurunegala District has the highest risk score among the three districts in the coconut triangle due to the relative high intensity of climate hazards. In some years, the ambient temperature has exceeded the threshold with possible implications for yield. There is a clear relationship between annual coconut production and Colombo retail price. The current household coconut consumption of 30 nuts per month is beyond the reach of the average household given the current prices of coconut and the amount of household expenditure allocated (LKR 1,166) for coconut consumption. Given the highest food insecure population living in Colombo, the vulnerable groups in the Colombo city region will have difficulties affording coconuts and coconut oil. The current household practice of coconut usage which results in waste of a significant amount of nutrients along with coconut kernel refuses also has implications for household nutrition security.

Recommendations for building resilient coconut supply chains

- Climate change adaptation measures with a focus on moisture conservation by introducing modern irrigation systems are essential to maintain steady coconut production.
- The high volatility of coconut production and its impact on coconut oil production and prices prompt consumers to shift from coconut oil to palm oil and adulterated cooking oils. Therefore, the implementation of food quality and safety regulations is necessary.
- Steps should be taken to ensure optimum use of the limited coconut production without compromising nutritional availability by raising consumer awareness on preparation of coconut kernels for cooking purposes.

5.4 FISH SUPPLY CHAIN

The main climate hazards that impact marine fishing are wind, cyclones and heavy rains. The intensity of the hazard scores shows a mediocre relationship with national fish production. Of the wind/cyclone events around 70% of wind/cyclone events have contributed to increased risk at the production node, while around 65% of heavy rain events have contributed to the same. Often marine fish production decline is mainly driven by disturbances to fishing activities as a result of frequent cyclonic conditions in the Indian Ocean. The prices of major fish varieties move above the average when the hazard intensifies. Fish supplies to Peliyagoda fish market drop by as much as 40% to 50% and prices are known to fluctuate in the range of 30% to 40% compared to a normal day due to adverse weather in the production regions. Peliyagoda fish market is equipped with some reasonable facilities such as cold storage facilities. Extreme weather conditions can contribute to postharvest losses of fish as high as 40%. This is further aggravated by lack of facilities such as chilled storage and ice supplies at most of the fish landing sites. Further, the fishery harbours, anchorages and landing sites are poorly equipped and lack basic facilities.

There is clear evidence that capacity enhancement through pre- and posthazard event initiatives such as providing early warning to fisheries associations and compensation and emergency relief given to affected fisherman families can enhance fishermen resilience thereby mitigating production risk. Overall, the low capacity and high vulnerability of the upstream nodes of fish supply chains can be attributed to a number of factors ranging from socio-economic status and access to fishing gear and infrastructure. Among the three fishing belts assessed, the Northern fishing belt is the most vulnerable and risky region due to poor infrastructure.

Processors, exporters and supermarket chains have better infrastructure for transport, processing and storage. State-of-the-art processing technologies are locally available due to a highly developed fish export industry (64 fish processing and packing centres of which 34 are EU-approved). However, their capacities have not been explored to strengthen the domestic fish supply chains.

Potential risk at the consumption node is likely to be influenced by 69% and 87% of heavy rain and flood events in the Colombo city region respectively. From the consumers perspective, food safety and quality of fish is a serious concern. According to estimations, the available per capita fish supply is not sufficient to meet the current requirements. Moreover, given the current HH expenditure allocated for fish (LKR 3,183/month), fish becomes beyond the reach of the average HH in the Colombo city region. This implies that climate hazards in the fishing regions can have a direct impact on protein malnutrition in the Colombo city region.

Recommendations for building resilient fish supply chains

- Fish is not affordable to the average consumer in the city region. Therefore, marine fish harvest should be increased by using modern technologies and multiday fishing vessels which can withstand adverse weather to ensure adequate supply of fish at an affordable price.
- To reduce postharvest losses along the fish supply chain, improvements to supply chain infrastructure such as cold storage, cold chain transport and modern processing facilities are necessary.
- In the Peliyagoda fish market, fish wastage is significant with about 20% fish either spoiled or sent for dry fish production. This situation has to be studied and corrective actions need to be taken to minimize fish spoilage and wastage.
- Malpractices such as adulterating fish purchases with inedible fish parts reduce the amount available for consumption. Therefore, the mechanisms available to monitor quality, food safety and malpractices in the main fish markets in the city region should be strengthened.
- The opportunity to learn from the local export-based advanced fish processing industry has not been exploited by the domestic fish industry to upgrade infrastructure, technology and improve food safety and quality standards in the local fish supply chains. Therefore, interventions are necessary to encourage technology transfer from the export industry to the domestic fish industry.

5.5 IMPACT OF THE COVID-19 PANDEMIC ON THE COLOMBO CITY REGION FOOD SYSTEM

The Covid-19 pandemic impacted the city region food system mainly due to closure of Peliyagoda fish market and the Manning Market during the first and second waves. A significant proportion of Colombo city region inhabitants are vulnerable to climate change and pandemic shocks because their livelihoods are dependent on daily wages earned from the informal sector. Moreover, Colombo District is known to have the highest proportion of food insecure people in the country.

The vulnerability of most of the food supply chains became apparent during the unfolding of the pandemic. Low country vegetable prices dropped sharply compared to upcountry vegetable prices. The impact of the pandemic was severe at the Dambulla DEC with more days of closure and disturbance to low country vegetable supply channels compared to upcountry DECs such as Keppetipola and Nuwara Eliya and their supply channels. The rice prices at the initial stages of the pandemic remained below the average monthly prices of the previous year. The imposition of MRPs in April was not effective and led to shortages of rice in the market. With emergence of the second wave in October, the rice prices rose due to issues in the governance of the rice supply chain.

Although fish prices remained below average throughout 2020 this did not benefit consumers or impact the nutritional profile of consumers as consumption remained low. Coconut production dropped by 25% in March and April 2020 compared to the same months in 2019. This could be partially attributed to the seasonality and issues with mobilizing labour to harvest coconuts due to the pandemic situation.

Although the government relaxed transport restrictions to transport food items during the curfew and lockdowns, the major supermarket chains reported issues with cross-border transportation of vegetables from production regions to Colombo city region. Both major supermarket chains indicated production was not affected but procurements were affected due to the restrictions leading to shortage of food items on their shelves.

The government intervention in terms of payment of a relief grant to vulnerable groups during both waves of the pandemic was among the important steps taken. The government also encouraged home gardening and as a result the local food system in rural and peri-urban regions became active. During the pandemic people spent their spare time on home gardening and cultivating fallow lands. The pandemic period saw the emergence of alternate food supply chains including self-organizing food distribution systems, e-commerce platforms and social media interfacing. Peri-urban agriculture has significant potential to support CRFS in terms producing food within the Colombo city region and shortening the food supply chains. A sample profile of peri-urban agriculture in the Colombo CRFS is presented in Appendix VIII.

The poor availability of data related to the impacts of Covid-19 on food supplies and distribution is a serious limitation in identifying vulnerabilities in the food system and making recommendations to build resilient food systems in times of crises such as the Covid-19 pandemic.

Recommendations for building resilient food supply chains in times of crisis

- Maintain momentum of increased interest in home gardening and local food production.
- Identify best practices and innovative and efficient short supply chains; improve and replicate.
- Develop a mechanism to implement existing emergency preparedness plans focusing on coordinating, directing and monitoring of preparation and implementation of actions at the ground level.
- The data gaps on food supplies and distribution should be bridged.
- Steps need to be taken to ensure policy-level decisions are conveyed without delay to the ground level for implementation and information flow should be strengthened and made available to relevant stakeholders in a timely manner.

5.6 CITY REGION FOOD SYSTEM GOVERNANCE

A national perspective was adopted in examining governance-related issues of the city region food system due to the presence of strong rural-urban linkages in food supplies.

In Sri Lanka, climate change challenges are addressed by the Climate Change Secretariat (CCS) under the purview of the Ministry of Environment. The CCS has come up with a number of policies, strategies and plans to govern climate change challenges in Sri Lanka. Among them, the NCCAS and NAP are two important national initiatives. Moreover, there are policy initiatives at the provincial level such as the climate action plan of the Western province.

The early warning system in the country is coordinated by the National Disaster Management Centre (NDMC). Inefficiencies have been identified in the early warning systems due to poor resource allocation and lack of coherence and integration of the system. Early warning communication mechanisms are known to be poor and as a result recipients have less trust in them and are reluctant to respond to early warnings.

Agriculture insurance schemes are becoming important risk management strategies in the context of climate change to protect the livelihoods of farmers and fisherman. Innovative insurance schemes are emerging with some being piloted in Sri Lanka. The agricultural insurance sector is far behind in terms of the climate challenges posed to the agricultural sector.

The complex multilevel governance structure in place to address climate change issues creates many challenges to coordinate and integrate a diverse set of institutions entrusted with responsibilities at different scales, viz., national, provincial, district and local levels.

Recommendations for city region food system governance

- The best approach to capitalize on multilevel governance is to set up an effective coordination mechanism, participatory decision-making, build capacity and allocate sufficient resources.
- The early warning systems should be strengthened through resource allocation and coherence and integration of the system and build stakeholder trust.
- Agricultural insurance as a risk management strategy has failed, evidenced by poor uptake. Therefore, it is necessary to move away from the outdated indemnity-based

insurance to more innovative insurance products such as weather-indexed insurance, block chain insurance using block chain technology.

5.7 INDICATOR FRAMEWORK FOR A CLIMATE-RESILIENT COLOMBO CITY REGION FOOD SYSTEM

Table 47 presents possible indicators that can be used to monitor progress of measures to build resilience of the Colombo city region food system. The indicators are presented under four priority areas viz., reduce vulnerability of food production, sustainable/resilient value chains, reduce vulnerabilities to food supply and distribution in the city region, reduce vulnerabilities at the household level and strengthen food system governance.

Table 47. Indicator framework for building resilience of Colombo CRFS to climate shocks and other stresses

Overarching objective	Possible indicators (how the change will be measured)	Comment
Reduce vulnerability of food production	An increased number of farmers adopting climate-smart agriculture practices.	The number of farmer adopting incremental adaptation measures can be used as a baseline.
	An increased number of farms with climate change adaptation plans.	A baseline needs to be established.
	An increased number of farmers/fishers using early warning in making farm/fishing decisions.	Utilization of early warning systems are low due to lack of trust.
	An increased number of farmers/fishers enrolling in insurance schemes.	Adoption of insurance is very low.
	An increased number of farmers linked to vertically integrated supply chains.	Link farmers to supermarket chains and contract farming.
	An increased number of farmers receiving technical support and training to build resilient farming systems.	The baseline needs to be established.
	An increased number of multiday fishing vessels in use.	Currently, the number of multiday fishing vessels is low (11%).
	Percent increase in investment to improve agriculture and fisheries infrastructure by both private and public sectors.	Prioritize agricultural investment on infrastructure (R&D, capacity building etc.).
Reduce vulnerabilities to food supply and distribution in the city region	An increased number of alternate food supply chains to the city region.	Currently, food is supplied through traditional supply chains dominated by DECs.
	Reduction in food supply through traditional supply chains to the city region.	Currently, about 85% of vegetable supplies comes through the traditional supply chain.
	Reduction in food loss along supply chains.	Currently losses are as high as 40%.

	Reduction in price volatility of main commodities at the distribution nodes.	Price volatility is high (30% to 40%).
	An increased number of cold chain/storage facilities.	Currently, very low to negligible in the traditional vegetable supply chain.
	An increase in investment on improving facilities at DECs.	DECs are poorly equipped.
	An increased number of households engaged in peri-urban agriculture.	Strengthening existing programmes to promote home gardening and peri-urban agriculture.
	An increased percentage of food supply from peri-urban agriculture to the city region.	Currently food supply from peri-urban agriculture to the city region is very low to negligible.
	An increased number of supply chain actors using ICT platforms to enhance supply chain efficiency.	ICT is not effectively used despite access and affordability of technologies; e.g. to match the demand and supply of vegetables and fish.
	An increased number of actions to maintain and monitor rice inventories at the national and city region level.	Currently public data are not available.
Reduce vulnerabilities at the household level	Reduction of food insecure/malnourished HHs in the city region.	The city region has the highest food insecure population in the country.
	Reduction in price volatility at the retail level.	Retail price volatility has a direct link with climate hazards.
	An increase in actions taken to subsidize prices for those populations most at risk of food insecurity/malnutrition.	Some actions taken during the Covid-19 pandemic proved effective.
	Reduction in incidents reported related to food quality and safety issues.	Frequently reported in the media, need compilation and verification of reports.
	Improvement in anthropometric measurements of children in the city region.	Can be verified by checking MOH records.
	A decrease in dependency ratio in the city region DSDs.	Some city region DSDs have a high dependency ratio.
Strengthen food system governance	An increased number of activities of the core group of institutions set up to build CRFS resilience.	A core group was set up recently. To make use of the multilevel governance to the advantage of building CRFS resilience it is necessary to have effective coordination mechanisms, participatory decision-making, capacity development and sufficient resources.
	An increase in the number of policies, strategies and actions related to climate change translated into actions at the grass-roots level.	Many national-level policies, strategies and action plans are available, but implementation is slow.
	An increased number of actions to improve/safeguard sanitation and food safety in public health plans and strategies.	To monitor chemical contamination in rice, vegetables, coconut oil and fish.

	Increase in investment to strengthen core group activities to build CRFS resilience.	A core group was set up recently.
	An increase in public-private partnerships to enhance CRFS resilience.	Initiated along with the setting up of the core group.

Source: Compiled based on CRFS indicator framework.

REFERENCES

Adhikarinayake, T. B., Palipana, K. B., & Müller, J. 2006. "Quality change and mass loss of paddy during airtight storage in a ferro-cement bin in Sri Lanka." *Journal of Stored Products* 42(3), 377-390.

A Landscape Analysis of Rice Fortification in Sri Lanka an Overview. 2017 . Ministry of Health, Nutrition and Indigenous medicine In collaboration with World Food Programme.

Abeysekara, M., Prasada, D., & Pathiraja, P. 2020. "Equilibrium Relations in the Coconut Sector: An Analysis of Fresh Nut, Oil and Desiccated Coconut Market in Sri Lanka for the Period 1956-2017." *Tropical Agricultural Research,* 31 (1), 01-12.

Abeysekera, T., & Abeysekera, S. . 2007. "Alternative supply chain management practices and the performance of marketing channels in fresh fruit and vegeyable in Sri Lanka." Lotus Pang SuanKaeo Hotel, Chiang Mai, Thailand, 41.

Abeysinghe, N. P. 2020. "Created a rice mafia after eating God's rice. ." *Silumina.lk.* 10 17.

Agstat. 2019. *Agricultural statistics.* Vol. xvi. Socio Economic and Planning Centre, Department of Agriculture, Peradeniya, Sri Lanka.

Agstat. 2019. *Pocket book of agricultural statistics.* Vol. xvi. Socio Economic and Planning Centre, Department of Agriculture, Peradeniya, Sri Lanka.

Ahmed, M & Suphachalasai, S. 2014. "Assessing the costs of climate change and adaptation in South Asia."

Akhiljith, P. J., Liya, V. B., Rojith, G., Zacharia, P. U., Grinson, G., Ajith, S., ... 2019. "Climatic Projections of Indian Ocean During 2030, 2050, 2080 with Impications on Fisheries Sector." *Journal of Coastal Research,* 86(SI), 198-208.

Akram, N., & Hamid, A. . 2014. " Climate change and human security in South Asia." *Science International* 26(2), 801-808.

Amarasingha, R. K., Suriyagoda, L. D. B., Marambe, B., Galagedara, L. W., & Punyawardena, . 2018. "Impact of climate change on rice yield in Sri Lanka: a crop modelling approach using Agriculture Production System Simulator(APSIM)." *Sri Lanka Journal of Food and Agriculture* 4(1).

Amarasinghe (Ph.D), O., & Piyasiri, K. 2020. *Daily News.* 11 17. http://dailynews.lk/2020/11/17/Features/233714/multiple-shocks-covid-19-and-tragedy-fisheries.

Amarasinghe, O. 2020. "Sri Lanka: Action stations." *Samudra Report,* (Samudra Report,) (82), 11-13.

Amarasinghe, O., & Bavinck, M. 2011. "Building resilience: fisheries cooperatives in southern Sri Lanka .In Poverty mosaics:Realities and Prospects in small-scale fisheries." *Springer* 383-406.

Amaratunga, V., Wickramasinghe, L., Perera, A., Jayasinghe, J., & Rathnayake, U. 2020. "Artificial neural network to estimate the paddy yield prediction using climatic data." In *Mathematical Problems in Engineering, 2020.*

Anon. (2008). *Analysis of fisheries sector in Sri Lanka.* Retrieved from http://www.jps.lk/research/fishery_sector_020708/reserarch%20_highlight_fishery_sector.pdf

Arulananthan, K.(n.d.). n.d. "Climate Change Research on Fisheries and Aquaculture: A Review of current status." *Workshop on Present Status of Research Activities on Climate Change Adaptations(Ed. B. Marambe).* Colombo: Sri Lanka Council for Agricultural Research policy. pp 121-126.

Athauda, S., &Chandraratna, N. 2020. "Fisheries Sector Contribution for Sustainable Food System:Past,Present, and Future In Agricultural Resesrch for Sustainable Food System in Sri Lanka." *Springer* pp. 333-349.

Athukorala, P., Ginting, E., Hill, H., & Kumar, U. (Eds.). 2017. *The Sri Lankan Economy:.* Asian Development Bank.

Athulathmudali S, Balasuriya A, Fernando K. 2011. *An exploratory study on adapting to climate change in coastal areas of Sri Lanka.* Working Paper Series No. 18, Colombo: Centre for Poverty Analysis .

Awanthi, M. G. G., Navaratne, S. B., & Navaratne, B. J. C. 2017. "Effect of storing time and temperature on milling quality of par-boiled and raw rice of an improved variety, at 362 and a traditional variety,Kuruluthuda." *Tropical Agricultural Research and Extension,* (Tropical Agricultural Research and Extension,) 20(1-2).

Awanthi, M. G. G., Navaratne, S. B., Jinendra, B. M. S., & Navaratne, C. M. 2018. "Effect of Rising Global Temperature on Dry Mass Loss of Stored Paddy." *International Journal of Scientific & Engineering Research* Volume 9, Issue 12.

Babu, A. T., Krupnik, T. J., Thilsted, S. H., & McDonald, A. J. 2020. *Key indicators for monitoring food system disruptions caused by the COVID-19 pandemic: Insights from Bangladesh towards effective response.* Food Security. https://doi.org/10.1007/s12571-020-01083-2

Bandara, S. M. 2021. *Fifteen rupees worth of nutrition is obtained from a 100 rupee cocunt.* March 07. https://divaina.com/sunday/index.php/visheshanga2/16803-2021-02-24-09-20-75.

Bene, C. 2020. ". Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks." *Food Security* 12, 805-822. https://doi.org/10.1007/s12571-020-01076-1.

Bindoff, N.L., W.W.L. Cheung, J.G. Kairo, J. Arístegui, V.A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M.S. Karim, L. Levin, S. O'Donoghue, S.R. PurcaCuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson,. 2019. "Changing Ocean, Marine Ecosystems, and Dependent Communities. ." Edited by D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M.Weyer H.-O. Pörtner. IPCC Special Report the Ocean and Cryosphere in a Changing .

Biradar, C. M., Thenkabail, P. S., Noojipady, P., Li, Y., Dheeravath, V., Turral, H.,Mohideen, S. 2009. "A global map of rainfed cropland areas (GMRCA) at the end of last millennium using remote sensing." International Journal of Applied Earth Observation and Geoinformation. 11(2), 114-129. doi: http://dx.doi.org/10.1016/j.jag.2008.11.002.

Blasiak R, Spijkers J, Tokunaga K, Pittman J, Yagi N, Österblom H. 2017. " Climate change andmarine fisheries: Least developed countries top global index of vulnerability." *PLoS ONE* 12(6). doi:https://doi.org/10.1371/journal.pone.0179632.

Blockchain Crop Insurance.2019. *Forkast. News.* July 02. https://forkast.news/blockchain crop-insuarance-big-boost-for-farmers -in-sri-lanka/.

Brinkman, H. J., De Pee, S., Sanogo, I., Subran, L., & Bloem, M. W. 2010. "High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health." *The Journal of nutrition* 140(1), 153S-161S.

Burchfield, E. K., & Gilligan, J. 2016. "Agricultural adaptation to drought in the Sri Lankan dry zone." *Applied Geography* 77, 92-100. doi:https://doi.org/10.1016/j.apgeog.2016.10.003.

Cai, Y., Bandara, J. S., & Newth, D. 2015. "A framework for integrated assessment of food production economics in South Asia under climate change. Environmental Modelling & software." doi:http://dx.doi.org/10.1016/j.envsoft.2015.10.024.

CBSL. 2019a. Annual report 2019

CBSL. 2019b. Economic and social statistics of Sri Lanka

CBSL. 2020. Annual Report: COVID-19 and Sri Lanka: Challenges, Policy Responses and Outlook. Central Bank of Sri Lanka.

CDA. 2016. Annual Report. Coconut Development Authority of Sri Lanka

CDD conducts online. 2020. "CDD conducts online coconut auction for first time." Dailynews. 04 10.

Chakraborty, S., & Newton, A. C. 2011. "Climate change, plant diseases and food security: an overview." *Plant Pathology* 60(1), 2-14. doi:10.1111/j.1365-3059.2010.02411.x.

Chandrasiri, S., Galagedara, L. & Mowjood, M. 2020. "Impacts of rainfall variability on paddy production: A case from Bayawa minor irrigation tank in Sri Lanka." *Paddy Water Environ* 18, 443–454. doi:https://doi.org/10.1007/s10333-020-00793-9.

Chithranayana, R., & Punyawardena, B. 2014. "Adaptation to the vulnerability of paddy cultivation to climate change based on seasonal rainfall characteristics." *Journal of the National Science Foundation of Sri Lanka* 42(2).

Church J.A & White N.J. 2011. "Sea-level rise from the late 19th to the early 21st century." *SurvGeophys* 32:585–602. doi:doi:10.1007/s10712-011-9119-1.

Cline, W. R. 2007. *Global warming and agriculture: Impact estimates by country.* Peterson Institute.

Closure of Manning market. 2020. "Closure of Manning Market." *Adaderana.* 04 22. http://sinhala.adaderana.lk/sports/135530.

Complaint about a company. 2021. "Complaint about a company." *NEWS.* 02 20. https://www.newsi.lk/beer/?fbclid=IwAR2vANnrtsLlIPnv9gr0Uc66uJeFWvT1T2SC96NT6_gumrQRd4GDh8KcFBI.

Corona spreads rapidly. 2020. "Corona spreads rapidly." *Lanka Eye Witnesses.* 10 25.

Davis, K., Gephart, J., & Gunda, T. 2015. "Sustaining food self-sufficiency of a nation: The case of Sri Lankan rice production and related water and fertilizer demands." *Ambio* 1-11. doi:doi:10.1007/s13280-015-0720-2.

DCS. 2015. Food balance sheet, 2012/2013. Colombo, Department of Census and Statistics, Sri Lanka

DCS. 2017. Demographic and Health Survey 2016. Colombo, Department of Census and Statistics, Sri Lanka

DCS. 2019a. Agricultural Household Survey 2016/17, Department of Census and Statistics, Sri Lanka.

DCS. 2019b. Food Balance Sheet 2013-2017, Department of Census and Statistics, Ministry of Economic Reforms and Public Distribution.

DCS. 2020a. Sri Lanka Statistical Information Service, Department of Census and Statistics, Sri Lanka

DCS.2020b. Maps/The data section for Corona Pandemic *related operations assistance*, Department of Census and Statistics.

DSC. 2021. Paddy Statistics, Department of Census and Statistics, Sri Lanka

De Costa, W. 2010. "Adaptation of Agricultural Crop Production to Climate Change: A Policy Framework for Sri Lanka." *Journal of the National Science Foundation of Sri Lanka* 38 (2):79-89.

De Costa, W. A. J. M. 2020. "Increasing Climate Resilience of Cropping Systems in Sri Lanka. . In Agricultural Research for Sustainable Food Systems in Sri Lanka." *Springer* 107-157. doi:https://doi.org/10.1007/978-981-15-3673-1_6.

De Costa, W.A.J.M. 2008. "Climate change inSri Lanka: myth or reality? Evidence from long term meteorological data." *Journal of the National Science Foundation of Sri Lanka* 36 (special issue): 63-68. doi:10.4038/jnsfsr.v36i0.8048.

De Silva, A. 2010. *Effects of the global financial crisis on the food security of poor urban households; Case study Colombo, Sri Lanka.* Faculty of Medicine , University of Colombo.

De Silva, C. S., Weatherhead, E. K., Knox, J. W., & Rodriguez-Diaz, J. A. 2007. "Predicting the impacts of climate change—A case study of paddy irrigation water requirements in Sri Lanka." *Agricultural water management* 93(1-2), 19-29.

De Silva, D. M. D. 2016. *Community based climate change adaptations: lessons learnt from small-scale fisheries of the South coast of Sri Lanka.* In Coping with Climate Change and Variability: lessons from Sri Lankan communities, Global Environment Facility Small Grantsprogramme in Sri Lanka.

Development of local canned fish. 2020. "Development of local canned fish." *Dailynews.* 07 15.

Devereux, S., Béné, C., & Hoddinott, J. 2020. "Conceptualising COVID-19’s impacts on household food security." *Food Security* 12: 769-772. doi:https://doi.org/10.1007/s12571-020-01085-0.

Deyshappriya, N. P. R.,. 2019. "An Empirical Analysis on Food Insecurity in Sri Lanka. Empirical Economic Review." 2(2): 81-105. doi: 10.29145/eer/22/020105.

Deyshappriya, N. R. 2019. "An Empirical Analysis on Food Insecurity in Sri Lanka. Empirical Economic Review." 2(2): 81-105.

Dharmarathna, W. R. S. S., Herath, S., & Weerakoon, S. B. 2014. "Changing the planting date as a climate change adaptation strategy for rice production in Kurunegala district, Sri Lanka." *Sustainability science,* 9(1): 103-111.

Dharmathilake, N. R. D. S., Rosairo, H. S. R., Ayoni, V. D. N., & Herath, R. M. 2020. "Implications of Post-Harvest Losses and Acreage Response of Selected Up-Country Vegetables from Nuwara-Eliya District in Sri Lanka on Sustained Food Security." *Journal of Agricultural Sciences–Sri Lanka* 15(1).

Dissanayake, C. A. K., Wasala, W. M. C. B., Gunawardhane, C. R., Wijewardhane, R. M. N A., Herath, M. M., &Beneragama, C. K. 2017. "Introduction of plastic crates to vegetable wholesalers in major economic centers in Sri Lanka: why do people refuse it?" *IV International Conference on Postharvest and Quality Management of Horticultural Products of Interest for Tropical Regions.* 151-156.

DMC. 2021. *DMC report*, Disaster Management Centre,Ministry of Defense Sri Lanka.

DSC. 2020*. Economics Statistics of Sri Lanka – 2020.*, Sri Lanka Statistical Information Service, Department of Census and Statistics (DCS).Sri Lanka.

Dubbeling, M.; Carey, J.; Hochberg, K. 2016. *The Role of Private Sector in City Region Food Systems. Part I.* Overall Analysis Report, : Leusden, The Netherlands; FBKN: The Hague, The Netherlands.: RUAF Foundation.

Dueri, S., Bopp, L., & Maury, O. 2014. "Projecting the impacts of climate change on skipjack tuna abundance and spatial distribution." *Global Change Biology* 20(3): 742-753.

EDB. 2019. *Industry Capability Report-Coconut and coconut Based Products*, Export Development Board (EDB), Sri Lanka.

Edirisinghe, K., Wansapala, J., &Wickramasinghe, I. 2018. "Review of marine fishery status along the supply chain in Sri Lanka." *International Journal of Food Science and Nutrition* 3 (4): 10-23.

Edirisinghe, U. A. S. K., Wickramasinghe, I., &Wansapala, M. A. J. . 2019. "Factors Affecting to Freshness Quality of Selected Tuna Fish Varieties along the Supply Chain." *International Research Symposium.* University of Vocational Technology, Ratmalana, Sri Lanka.

Eraminigammana, S. 2020. "The farmer who fell down due to the closure of the Dambulla Economic Center." *Silumina.lk.* 04 11.

Ericksen, P. J. 2008. "Conceptualizing food systems for global environmental change research." *Global Environmental Change* 234-245. doi:http://dx.doi.org/10.1016/j.gloenvcha.220.09.02.

Eriyagama, N., Smakhtin, V., Chandrapala, L., & Fernando, K. 2010. "Impacts of climate change on water resources and agriculture in Sri Lanka: a review and preliminary vulnerability mapping." *Colombo: International Water Management Institute.*

Esham, M., & Usami, K. 2006. "Procurement behavior of the fruit and vegetable industry in Sri Lanka." *Journal of Agricultural Sciences–Sri Lanka* 2(3).

Esham, M., Jacobs, B., Rosairo, H. S. R., & Siddighi, B. B. 2018. "Climate change and food security: a Sri Lankan perspective." *Environment, Development and Sustainability* 20(3): 1017-1036.

Esham, M., Kobayashi, H., Usami, K., & Matsumura, I. 2006. "Factors influencing crop diversification in Sri Lanka." *Japanese Journal of Farm Management* 44(1): 148-152.

Esham, M. 2021. "Towards food security in Sri Lanka: A framework to strengthen the adaptive capacity of the food system to climate change." Unpublished manuscript.

FAO.2019. Report on cost-benefit analysis of the Monitoring, Control and Surveillance (MCS) System and tools developed by Sri Lanka, Colombo: Food and Agriculture Organization.

FAO (Food and Agriculture Organization of the United Nations) and WFP (World Food Programme). (2017). Special Report FAO/WFP Crop and Food Security Assessment Mission to Sri Lanka. Available at: http://www.fao.org/3/a-i7450e.pdf

FAO GIEWS.2020. *FAO GIEWS FPMA Tool*. Monitoring and analysis of food prices. https://fpma.apps.fao.org/giews/food-prices/tool/public/#/dataset/domestic.

FAO. 2016. *Working document*. food and Agriculture Organization of the United Nations ,City region food system situation analysis., Colombo, Sri Lanka.

FAOSTAT. 2015. Statistical database. Food and Agriculture Organization.

Farzan, Z. 2020. "Rice Mill operations declared as an essential service." *Newsfirst.* 04 10. https://www.newsfirst.lk/2020/04/10/rice-mill-operations-declared-as-an-essential-service/.

Fernando, A. P. S., Perera, A. M. S., & Karunagoda, K. 2010. "Instability of paddy production and regional food insecurity in Sri Lanka." *national conference on water food security and climate change in Sri Lanka.* 33-45.

Fernando, M. D., Palipane, K. B., & Adhikarinayake, T. B. 1988. "Improvement of farm level grain storage methods in Sri Lanka." *Sri Lankan Journal of Post-Harvest Technology.*

Fernando, M. T. N., Zubair, L., Peiris, T. S. G., Ranasinghe, C. S., & Ratnasiri, J. 2007. *Economic value of climate variability impacts on coconut production in Sri Lanka.* Working, AIACC, 45.

Fisheries Sector Development Strategy of Sri Lanka. 2010. Ministry of Fisheries and Aquatic Resource Development. .

Foreign Agricultural Service. 2020. Sri Lanka - Temporary Suspension of Imports Due to COVID-19. Colombo: https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Sri% 20Lanka%20-

%20Temporary%20Suspension%20of%20Imports%20Due%20to%20COVID19%20_Colombo_Sri%20Lanka_04-15-20
Galanakis, C. M. 2020. "The Food Systems in the Era of the Coronavirus (COVID-19) Pandemic Crisis." *Foods* 9(4): 523. doi: https://doi.org/10.3390/foods9040523.
Galappattige, A. 2020. *Sri Lanka grain and feed annual.* Global Agriculture Information , USDA Foreign Agricultural Service. Network.https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileNa.
Galappattige, A. 2019. *Sri Lanka grain and feed annual2019.* Global Agriculture Information, USDA Foreign Agricultural Service. Network.http://agriexchange.apeda.gov.in/MarketReport/Reports/Rice_Rebounds_Grain_and_Feed_Annual_2019_Colombo_Sri_Lanka_9-16-2019.pdf.
Gephart, J.A., et al. 2017. "Shocks to fish production: Identification, trends, and consequences." *Global Environmental Change42* 24-32.
Gnanaseelan C., Roxy M.K., Deshpande A. 2017. "Variability and Trends of Sea Surface Temperature and Circulation in the Indian Ocean." Edited by Nayak S. Rajeevan M. *Springer Geology.* (Springer Singapore). doi: https://doi.org/10.1007/978-981-10-2531-0_10.
Govt to purchase. 2020. "Govt. to purchase." *Newsfirst.* 04 14. https://www.newsfirst.lk/2020/04/14/govt-to-purchase-produce-from-farmers-in-four-districts/.
Gregory, P. J., Ingram, J. S. I., & Brklacich, M. 2005. "Climate change and food security Philosophical Transactions of the Royal Society of London B." *Biological Sciences,* 360(1463): 2139-2148. doi:https://doi.org/10.1098/rstb.2005.1745.
Guaranteed price. 2020. "Guaranteed price." *The morning.* 04 24. The morning. https://www.themorning.lk/guaranteed-price-for-14-crops-cabinet-approves-prices-for-yala-season/.
Gunarathna, R. T., & Bandara, Y. M. 2020. " Post-Harvest Losses and the Role of Intermediaries in the Vegetable Supply Chain." *2020 Moratuwa Engineering Research Conference (MERCon).* IEEE. 378-383.
Harris, J., Depenbusch, L., Pal, A. A., Nair, R. M., & Ramasamy, S. 2020. "Food system disruption: initial livelihood and dietary effects of COVID-19 on vegetable producers in India." *Food Security* 1-11. doi:https://doi.org/10.1007/s12571-020-01064-5.
Hewawasam, V., & Matsui, K. 2019. "Historical development of climate change policies and the Climate Change Secretariat in Sri Lanka." *Elsevier Ltd* 101(10): 255-261. doi:10.1016/j.envsci.2019.09.001.
Hijioka, Y., Lin, E., Pereira, J., Corlett, R., Cui, X., Insarov, G.,Mach, K. 2014. "Working Group II contribution to the IPCC Fifth Assessment Report Climate Change." Chapter 24, 1858-1925.
Hippola, H., Jayasooriya, E., Jayasiri, G., Randil, C., Perera, C., Sylva, K., & Dissanayake, P. 2018. "Gap assessment of warning and dissemination process of early warning system in coastal areas of Sri Lanka." *International Conference on Sustainable Built Environment.* Springer. 36-44. doi:https://doi.org/10.1007/978-981-13-9749-3 4.
Hobbs, J. E. 2020. "Food supply chains during the COVID-19 pandemic." *Canadian Agricultural Economics Society* 171-176. doi:https://doi.org/10.1111/cjag.12237.
IFPRI South Asia. 2020 https://Southasia.ifpri.info/2020/05/13/how-agri-food-chains-in-sri-lanka-fared-during-the-strengent-covid-19-control-measuers/.
Islandwide rice shortage. 2020. "Islandwide rice shortage." *Srilanka mirror.* 05 21. https://sinhala.srilankamirror.com/biz/23987-divaina-pura-mol-himiyan.

Japan International Cooperation Agency (JICA*).* 2013 . Democratic Sociality Republic of Sri Lanka Data Collection Survey on Agricultural Distribution Network and Marketing, Final Report, JICA, Colombo, Sri Lanka.

Jayalath, K. 2018. *Weather variability and coconut production in Sri Lanka: State contingent Analysis.* School of Agriculture and Food Sciences, The University of Queensland.

Jayalath, K., Punyawardena, B., Silva, P., Hemachandra, D., & Weerahewa, J. 2020. "Climate Change and Extreme Events in WL1a Agro-ecological Zone of Sri Lanka:Implications on Coconut Production." *Tropical Agricultural Research* 31(4): 13-25.

Jayamanne, D. 2020. "COVID-19 cannot spread through well-cooked fish- Dr. Sridharan." *Ceylontoday.* 10 26. y. https://ceylontoday.lk/news/covid-19-cannot-spread-through-well-cooked-fish-dr-sridharan.

Jayasinghe. C. 2020. "Sri Lanka coconut auctions go online." *Economynext.* 05 13.

Jayatissa, R. L. N., Wickramasinghe, W. D., & Piyasena, C. 2014. *Food consumption patterns in Sri Lanka.* Hector Kobbekaduwa Agrarian Research and Training Institute.

Jayawardena, R., Byrne, N. M., Soares, M. J., Katulanda, P., & Hills, A. P. 2013. "Food consumption of Sri Lankan adults: an appraisal of serving characteristics." *Public health nutrition* 16(4): 653-658.

Jayawardena, R., Byrne, N. M., Soares, M. J., Katulanda, P., & Hills, A. P. 2013. "Food consumption of Sri Lankan adults: an appraisal of serving characteristics." *Public health nutrition* 16(4): 653-658.doi: 10.1017/S1368980012003011

Jayawardena, R., Jeyakumar, D. T., Gamage, M., Sooriaarachchi, P., & Hills, A. P. 2020. "Fruit and vegetable consumption among South Asians: A systematic review and metaanalysis." *Clinical Research & Reviews.*

Jayawardhana, M., & Warnakulasooriya, B. 2020. "Impact of Problems associated with Supply Chain Management Practices of Wholesalers on their Business Performance in the Coconut Industry in Sri Lanka with special reference to Kurunegala District." *Vidyodaya journal of Managment* 06(1): 59-87.

Kikuchi, M., Weligamage, P., Barker, R., Samad, M., Kono, H., &Somaratne, H. M. 2003. *Agro-well and pump diffusion in the Dry Zone of Sri Lanka: Past trends, present status and future prospects.* Research Report 66, Colombo,Sri lanka: International Water Managment Institute.

Kodithuwakku, S. S., & Weerahewa, J. 2014. "Supermarkets and their effects on smallholder vegetable farmers in Sri Lanka:An exploratory case study." *Journal of Agriculture Economics and Rural Development* 62,71.

Korale Gedara, P. M., Ratnasiri, S., & Bandara, J. S. 2015. "Does asymmetry in price transmission exist in the rice market in Sri Lanka?" *Applied Economics* 1-15. doi:10.1080/00036846.2015.1125427.

Kumar, A., Padhee, A. K., & Kumar, S. 2020. "How Indian agriculture should change after COVID-19." *Food Security* 12: 837-840. doi:https://doi.org/10.1007/s12571-020-01063-6.

Kumara, S. K., Weerakkody, R., &Epasinghe, S. 2015. *Viability of Controlled Environmental Agriculture for Vegetable Farmers in Sri Lanka.* Research Report No: 179, Hector Kobbekaduwa Agrarian Research and Training Institute. ISBN: 978-955-612-178-0.

Laborde, D., Martin, W., Swinnen, J., & Vos, R. 2020. "COVID-19 risks to global food security. Washington, DC." *American Association for the Advancement of Science.* (American Association for the Advancement of Science.) 369(6503): 500-502. doi:10.1126/science.abc4765.

Lam, V.W.Y., Allison, E.H., Bell, J.D. et al. 2020. "Climate change, tropical fisheries and prospects for sustainable development." *Nat Rev Earth Environ* 1: 440–454. doi:https://doi.org/10.1038/s43017-020-0071-9.

LBO. 2013. "Sri Lanka mulls safety rules on fishermen as monsoon kills 54." *Lanka Business Online.* 06 12. doi: https://www.lankabusinessonline.com/sri-lanka-mulls-safetey-rules-on-fishermen-as-monsoon-kills-54/.

Marambe, B., & Silva, P. 2020. "A sixty-day battle to tackle food security – response of the Sri Lankan government to the COVID-19 pandemic." *Sri Lanka Journal of Food and Agriculture* 6(1): 1-5. doi:http://doi.org/10.4038/sljfa.v6i1.77.

Marambe, B., Dissanayake, S., Silva, P., & Weerahewa, J. 2020. "Analysis of existing current institutional coordination mechanisms, policies, strategies and action plans related to CRFS & Successful interventions and lessons learned on climate resilient good practices within local and international food systems." (Faculty of Agriculture, University of Peradeniya).

Marambe, B., Pushpakumara, D.K.N.G., Silva, P., Weerahewa, J. and Punyawardena,B.V.R. 2013. "Climate change and household food security in home gardens of Sri Lanka." Edited by H.A.J. Gunathilake, J.M.D.T. Everard C.S. Ranasinghe and A.D. Nainanayake H.P.M. Gunasena. *International Conference on Climate Change Impacts and Adaptations Food and Environmental Security.* Colombo, Sri Lanka. 87-100.

Mawilmada, N., Atapattu, S., Dela, J., Gunawardene, N., Weerasinghe, B., NandanaM. & Kumari, N. 2010. Sector Vulnerability Profile: Agriculture and Fisheries, ADB.

Mayadunne, G., & Romeshun, K. 2013. "Estimation of prevalence of food insecurity in Sri Lanka." *Sri Lankan Journal of Applied statistics* 14(1): 27-40. doi:http://doi.org/10.4038/sljastats.v14il.5875.

MFARD. 2018. *Fisheries Statistics 2019.* Ministry of Fisheries and Aquatic Resources Development.

MFARD. 2019. *Fisheries Statistics 2019.* Ministry of Fisheries and Aquatic Resources Development.

Million kilos of vegetables. 2020. "Million kilos of vegetables." *Runews.* 11 02.

Ministry of Agriculture. 2019. *Sri Lanka overarching agricultural policy.* Ministry of Agriculture., Sri Lanka. http://www.agrimin.gov.lk/web/images/Information_Act/Development/2019_08_19_Draft_OAP.pdf.

Ministry of Fisheries. 2020. Fisheries statistics-2020. Ministry of Fisheries, Colombo, Sri Lanka.

Mishra, V., Bhatia, U., & Tiwari, A. D. 2020. "Bias-corrected climate projections for South Asia from Coupled Model Intercomparison Project-6." *Scientific Data* 7(1): 1-13.

MoHNIM. 2017. *National food fortification workshop report.* Ministry of Health Nutrition and Indigenous Medicine, Sri Lanka.

MPIEA. 2020. Statistical Information on Plantation Crops-2018. Ministry of Plantation Industries & Export Agriculture. Sri Lanka

MPIEA. 2020. Statistical Information on Plantation Crops 2018. Ministry of Plantation Industries and Export Agriculture, Battaramulla

Msangi, S., Kobayashi, M., Batka, M., Vannuccini, S., Dey, M. M., & Anderson, J. L. 2013. *Fish to 2030: prospects for fisheries and aquaculture.* World Bank Report, 102.

Munasinghe, J. P., De Silva, A., Weerasinghe, G., Gunaratne, A., &Corke, H. 2015. "Food safety in Sri Lanka: problems and solutions." *Quality Assurance and Safety of Crops & Foods* 7(1): 37-44. doi:10.3920/QAS2014.x007.

Nandana, M., Mawilmada, N., Atapattu, S., Dela, J., Bellamawithana, A. 2011. *Climate Change Vulnerability Data Book- Maps and data by sector.* Ministry of Environment, Battaramulla.

Naotunna, N., Dayarathna, M., Maheshi, H., Amarasinghe, G., Kithmini, V.,Rathnayaka, M., Agampodi, S. 2017. "Nutritional status among primary school children in rural Sri Lanka; a public health challenge for a country with high child health standards." *BMC public health* 17(1): 57. doi: https://doi.org/10.1186/s12889-016-4001-1.

NARA. 2018. *Sri Lanka Fisheries Sector Outlook 2018*. National Aquatic Resources Research and Development Agency (NARA), Sri Lanka

Naveendrakumar, G., Obeysekera, J., Vithanage, M., & Center, S. L. S. 2019. *Journal of Dry Zone Agriculture,2019* (Faculty of Agriculture, University of Jaffna, Sri Lanka) 5(2): 38-47.

Naveendrakumar, G., Vithanage, M., Kwon, H. H., Iqbal, M. C. M., Pathmarajah, S & Obeysekera, J. 2018. "Five decadal trends in averages and extremes of rainfall and temperature in Sri Lanka." *Advances in Meteorology, 2018.*

Neththasinghe, D. 2017. "24 containers of palm oil destroyed. ." *Srilankanmirror.* 02 12. Srilankamirror.https://sinhala.srilankamirror.com/news/2428-palm-oil.

Nirmali, S., & Edirisinghe, J. 2010. " Food Demand Elasticities, Price Changes and Calorie Availability of Households in the Western Province of Sri Lanka."

Nissanka, S. P., Karunaratne, A. S., Weerakoon, W. M. W., Herath, R. M.,Punyawardena, B. V. R.,Delpitiya, P., et al. 2013. "Climate change impact on rice-based farming systems in Sri Lanka and adaptation strategies." Accessed 03 21, 2016. http://www.agmip.org/wp-content/uploads/2013/11/Rice-Sri-Lanka.pdf.

Osada, A., Sasiprapa, V., Rahong, M., Dhammanuvong, S., & Chakrabndhu, H. 1973. "Abnormal occurrence of empty grains of indica rice plants in the dry, hot season in Thailand." *Japanese Journal of Crop Science* 42(1): 103-109.

Padmajani, M. T., Aheeyar, M. M. M., & Bandara, M. A. C. S. 2014. *Assessment of pesticide usage in Up-Country vegetable farming in Sri Lanka.* HARTI Research Report No: 164, Hector Kobbekaduwa Agrarian Research and Training Institute, Colombo, Sri Lanka.

Palipana, K. B. 2000. "Milling and quality improvement in rice." Rice Symp 2000, Gannoruwa, Sri Lanka.

Pallawala, R. 2018. *Mapping of Institutional Arrangement in Sri Lanka for Climate Change Mitigation.* Colombo, Sri Lanka: Janathakshan GTE Limited.

Pallegedara, A. 2019. "Food consumption choice and demand by the Sri Lankan households." *Journal of Agribusiness in Developing and Emerging Economies.*

Pallegedara, A. 2019. "Food consumption choice and demand by the Sri Lankan households: Trends, drivers and policy implications." *Journal of Agribusiness in Developing and Emerging Economies* (Emerald Group Publishing) 9(5): 520-535. doi:https://doi.org/10.1108/JADEE-01-2019-0014.

Pathiraja, E., Griffith, G., Farquharson, B., & Faggian, R. 2017a. "The Economic Cost of Climate Change and the Benefits from Investments in Adaptation Options for Sri Lankan Coconut Value Chains." *System Dynamics and Innovation in Food Networks .* International European Forum. 460-485.

Pathiraja, E., Griffith, G., Farquharson, R., & Faggian, R. 2017. "Specifying and Testing an Equilibrium Displacement Model of the Coconut Market in Sri Lanka." 25: 55-86.

Pathiraja, E., Griffith, G., Farquharson, R., & Faggian, R. 2019. "The Cost of Climate Change to Agricultural Industries: Coconuts in Sri Lanka." *International journal Food system Dynamics* 10(5): 428-457.

Pathmeswaran, C., Lokupitiya, E., Waidyarathne, K., & Lokupitiya, R. 2018. "Impact of extreme weather events on coconut productivity in three climatic zones of Sri Lanka." *European Journal of Agronomy* 47-53.

Peiris, T. S. G., & Thattil, R.O. n.d. "Assessment of the effects of environmental factors on yield of coconut (Cocos nucifera L.)." *The Journal of the Coconut Research Institute of Sri Lanka (cocos)* 12: 01-17.

Peiris, T. S. G., Hansen, J. W., & Zubair, L. 2008. "Use of seasonal climate information to predict coconut production in Sri Lanka." *International Journal of Climatology:A Journal of the Royal Meteorological Society* 28(1): 103-110. doi:https://doi.org/10.1002/joc.1517.

Peiris, T., Thattiil, R., & Mahindapala, R. 1995. "An analysis of the effect of climate and weather on coconut (cocos nucifera)." *Experimental Agriculture* 31(04): 451-460.

Peng, S., Huang, J., Sheehy, J. E., Laza, R. C., Visperas, R. M., Zhong, X.,Cassman, K. G. 2004. "Rice yields decline with higher night temperature from global warming." *Proc Natl Acad Sci U S A* 101(27): 9971-9975.

Perera, C. 2020. "Rs.600 million allocated for purchasing fish." *Dailynews.* 04 10. https://www.dailynews.lk/2020/04/10/local/216294/rs600-million-allocated-purchasing-fish.

Perera, C., Jayasooriya, D., Jayasiri, G., Randil, C., Bandara, C., Siriwardana, C., & Kulatunga, A. 2020. "Evaluation of gaps in early warning mechanisms and evacuation procedures for coastal communities in Sri Lanka." *International journal of disaster resilience in the built environment* 11(3): 415-433. doi:https://doi.org/10.1108/IJDRBE-07-2019-0048.

Perera, K. B. P., Herath, H. M. L. K., Jayasinghe-Mudalige, U. K., Edirisinghe, J. C.,Udugama, J. M. M., & Wijesuriya, W. 2016. "Price Analysis of Selected Marine Fish Available in Colombo Fish Markets."

Perera, M., Kodithuwakku, S., & Weerahewa, J. . 2011. "Analysis of vegetable supply chains of supermarkets in Sri Lanka." *Sri Lankan Journal of Agricultural Economics* 6(1).

Closure of Manning market. 2020. "Closure of Manning Market." *Adaderana.* 04 22. http://sinhala.adaderana.lk/sports/135530.

Pfeffer WT, Harper JT, O'Neel S. 2008. "Kinematic constraints on glacier contributions to 21st-Century sea-level rise." *Science 321* 1340-1343. doi:10.1126/science.1159099.

Plan to restore. 2020. "plan to restore." *Dailymirror.* 03 11. http://www.dailymirror.lk/print/front_page/Plan-to-restore-civilian-life-on-May11-Specialgazette-to-be-issued/238-188007

IGP, PM Instructs. 2020. "PM Instructs IGP." *Newsfirst.* 03 28. https://www.newsfirst.lk/2020/03/28/pm-instructs-igp-to-remedy-obstructions-on-transportingfood-items/

Prasada, D.V.P. 2020. "Climate-indexed insurance as a climate service to drought-prone farmers: evidence from a discrete choice experiment in Sri Lanka." *Springer* 423-445. doi: https://doi.org/10.1007/978-3-030-36875-3_21.

Premalal, K.H.M.S. and Punyawardena, B.V.R. 2013. " Occurrence of extreme climatic events in Sri Lanka." *International Conference on climate change impacts and adaptations,.* 49–57.

Programme. 2017. "Crop and Food Security Assessment Mission to Sri Lanka." Special Report FAO/WFP. http://www.fao.org/3/a-i7450e.pdf.

Pulighe, G., & Lupia, F. 2020. "Food First: COVID-19 Outbreak and Cities Lockdown a Booster for a Wider Vision on Urban Agriculture." *sustainability* 12(12): 5012. doi:https://doi.org/10.3390/su12125012.

Ranasinghe, C. 2019. "Climate Change Impacts on Coconut Production and Potential Adaptation and Mitigation Measures: A Review of Current Status." Edited by

B.Marambe. *Workshop on Present Status of Research Activities on Climate Change Adaptations.* Colombo: Sri Lanka Council for Agricultural Research. 71-82.
Rannan-Eliya, R. P., Hossain, S. M. M., Anuranga, C., Wickramasinghe, R., Jayatissa, R., & Abeykoon, A. T. P. L. 2013. "Trends and determinants of childhood stunting and underweight in Sri Lanka." *Ceylon Medical Journal* 58(1).
Ratnasiri, S., Bandara, J. S., & Korale-Gedara, P. 2012. "Changing Incomes and Food Prices: The Implications for Rural and Urban Food Security in Sri Lanka."
Ratnasiri, S., Walisinghe, R., Rohde, N., & Guest, R. 2019. "The effects of climatic variation on rice production in Sri Lanka." *Applied Economics* 51(43): 4700-4710.
Recent Economic Developments: highlights of 2020 and prospects for 2021.2020. Central Bank of Srilanka. https://www.cbsl.gov.lk/sites/default/files/cbslweb_documents/publications/red/2020/Chapter_ 5_e.pdf

Rice mills declared. 2020. "Rice mills declared." *Presidential secretariast.* 04 10. https://www.presidentsoffice.gov.lk/index.php/2020/04/10/rice-mills-declared-an-essential-service/.

Rs.20 million. 2020. "Rs.20 million." *Matarapuwath.* 04 11. https://matarapuwath.blogspot.com/2020/04/200.html?spref=pi.

Rs. 5, 000 each for over 4 million. 2020. "Rs. 5,000 each for over 4 million." *Buisness News.* 04 03. https://www.buisnessnews.lk/2020/04/03/rs-500-each-for-over-4-million-sri-lankans-to-cone-with-covid-19/.

Sahn, D. E. 1988. "The effect of price and income changes on food-energy intake in Sri Lanka. ." *Economic Development and Cultural Change* 315-340.
Selliah, S., Applanaidu, S.-D., & Hassan, S. 2015. "Transmission of Global Food Prices to Domestic Prices: Evidence from Sri Lanka." *Asian social science* 11(12): 215.
Senalankadhikara, S. and Manawadu, L. 2010. "Rainfall fluctuation and changing patterns of agriculture practices." Edited by A. and Jinapala.K Evans. *National Conference on Water, Food Security and Climate Change in Sri Lanka.* BMICH, Colombo,Sri Lanka: International Water Management Institute (IWMI). 127-139.

Senanayake, S. M. P., & Premaratne, S. P. 2016. "An analysis of the paddy/rice value chains in Sri Lanka." *Asia-Pacific Journal of Rural Development* 26(1): 105-126.
Senanayake, S. M. P., & Premaratne, S. P. 2016. "An analysis of the paddy/rice value chains in Sri Lanka." *Asia-Pacific Journal of Rural Development* 26(1): 105-126.
Senaratne A, Perera N, Wickramasinghe K. 2009. *Mainstreaming climate change for sustainable development in Sri Lanka: Towards a national agenda for action.* Working Paper Series No. 14, Institute of Policy Studies, Colombo, Sri Lanka.
Sheikh, M. M., Manzoor, N., Ashraf, J., Adnan, M., Collins, D., Hameed, S.,Shrestha, M. L. 2015. "Trends in extreme daily rainfall and temperature indices over South Asia." *International Journal of Climatology,* 35(7): 1625-1637. doi: 10.1002/joc.4081.
Silva G.L.L.P. and Dematawewa C.M.B. 2020. "Livestock and Poultry to Assure Sustainability in the Food System." Edited by Weerahewa J., Dandeniya W. Marambe B. *Springer.* doi:https://doi.org/10.1007/978-981-15-2152-2_13.
Siriwardana, C., Jayasiri, G. P., & Hettiarachchi, S.S.L. 2018. "Investigation of efficiency and effectiveness of the existing disaster management frameworks in Sri Lanka." *Procedia engineering* 212: 1091-1098. doi:10.1016/j.proeng.2018.01.141.

Sivakumar, M. V., & Stefanski, R. 2010. "Climate Change in South Asia Climat echange and food security in South Asia ." *Springer* 13-30.
Sri Lanka co-operatives enter national rice supply chain. 2019. "Sri Lanka co-operatives enter national rice supply chain." *Lanka buisness news.* 01 20. http://www.lanakabuisnessnews.com/sri-lanka-co-operatives-enter-national-rice-supply-chain/.

Sri Lanka- Sanasa Insuarance. 2019. "Sri Lanka- Sanasa Insurance." *Agro insuarance.* 12 06. http://agroinsuarance.com/en/sri-lanka-sanasa-insuarance-partners-with-giz-to-launch-insuarance-app-for-local-farmers/.

Sri Lanka to imports. 2020. "Sri Lanka to import." *ColomboPage. News Desk.* 09 18. http://www.colombopage.com/archive_20B/Sep18_1600445864CH.php.

State initiative. 2020. "State initiative." *Newsfirst.* 04 04. https://www.newsfirst.lk/2020/04/04/state-initiative-to-make-sri-lanka-self-sufficient-people-advised-to-cultivate-at-homes/.

Suryani, S., Sariani, S., Earnestly, F., Marganof, M., Rahmawati, R., Sevindrajuta, S.,Mahlia, T. M. I. &Fudholi, A. 2020. "A comparative study of virgin coconut oil, coconut oil and palm oil in terms of their active ingredients." *Processes* 8(4): 402. doi:https://doi.org/10.3390/pr8040402.
UNSDG. 2020. *unsdg.un.org.* 07. https://unsdg.un.org/resources/un-advisory-paper-immediate-socio-economic-response-covid-19-sri-lanka.

Urban Agriculture Magazine. 2018. *Measuring Impact.* Ruaf. https://ruaf.org/document/urban-agriculture-magazine-no-34-measuring-impact/.
Vidanapathirana, R. 2020. "COVID-19 and its impact on food supply chains." *Dailynews.* 05 28.
Weddagala, T., De Silva, D., & Basnayake, B. . 2018. *Strategic Adaptions on Climate Shocks in Malleable Employment of Fishing Community by E–Skill Inventory: A Case of Southern Coast of Sri Lanka.* International Institute of Fisheries Economics & Trade.
Weerahewa, J. Hemachandra, D.& Roy, D. 2020. "How agri-food chains in Sri Lanka fared during the stringent COVID-19 control measures?" *IFPRI South Asia.*
Weerahewa, J., Kodithuwakku, S. S., & Ariyawardana, A. 2010. "The fertilizer subsidy programme in Sri Lanka, Case Study No 7-11 of the Program: Food policy fordeveloping countries." (Cornell University,Ithaca, NY.).
Weerahewa, J., Rajapakse, C., & Pushpakumara, G. 2013. "An analysis of consumer demand for fruits in Sri Lanka 1981-2010." *Appetite* 60: 252-258.
Weerakoon, W. M. W., & De Costa, W. A. J. M. 2009. *Impact of Climate Change on Rice Production in Sri Lanka.*
Weerasekara, P., Withanachchi, C., Ginigadda, G., & Ploeger, A. 2020. "Food and Nutrition-Related Knowledge, Attitudes, and Practices among Reproductive-age Women in Marginalized Areas in Sri Lanka." *International Journal Environ Res Public Health* 17(11): 3985. doi:0.3390/ijerph17113985.
Wickramasinghe, K. 2020. “Climate Insurance for Dry Zone Farmers in Sri Lanka: Prospects for Index Insurance”. ISBN978-955-7397-13-9, Agricultural Research Series Institute of Policy Studies, Sri Lanka.
Wijenayake, V., Wickramasinghe, B., Mombauer, D., Halkewela, M.,. 2019. *SLYCAN TRUST.*

Wijesooriya, W. A. N., &Priyadarshana, W. H. D. 2013. *Structure, Conduct, and Performance of Rice Milling Industry in Polonnaruwa and Hambantota Districts of Sri Lanka.* Research Report No:, Hector Kobbekaduwa Agrarian Research and Training Institute.

Wijesooriya, W. A. N., Champika, P. A. J., & Kuruppu, I. V. 2020. "The Paddy Farmers' Channel Choice and Links to the Public and Private Marketing Channels in Sri Lanka." *Applied Economics and Business* 4(1): 60-70.

Zervos, F. H. 2020. "Three ways Sri Lanka can deal with COVID-19 induced poverty." *Worldbankblog.org.* 10 21.

Zubair, L. 2002. "El Nino–southern oscillation influences on rice production in Sri Lanka." *International Journal of Climatology* 22(2): 249-260.

Zubair, L., Nissanka, S. P., Weerakoon, W. M. W., Herath, D. I., Karunaratne, A. S.,Prabodha, A. S. M.& Vishwanathan, J. 2015. *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project Integrated Crop and Economic Assessments.* Vol. part 2.

APPENDIXES

Appendix I

Incidents reported in the media on spoiled rice stock.

Date	Place	Description
05-04-2019	Kulutara	2,000 kg of expired rice for human consumption at wholesale shop
30-12-2019	Hingurakgoda	350,000 kg of exported rice was stocked until expiration date
26-02-2017	Colombo	2,550 kg of expired rice stock was found
04-04-2017	Pettah	17,150 kg of unsold hidden rice stock was confiscated
11-03-2017	Colombo 12	7,825 kg of expired keeri samba stock was found while repacking
03-12-2019	Rathna rice mills	Distributed repacked expired rice with chemical treatment
29-11-2019	Polonnaruwa Welikanda	New Rathna rice mill was sealed while repacking expired rice stock
31-12-2019	Hingurakgoda	Expired rice stock of 400,000 kg was found
24-07-2018	Ipalogama	Expired (not suitable for human consumption) rice stock was found at a rice mill during the polishing process for repacking
10-04-2020	Jaffna	Muslim rice transporter was arrested while transporting expired rice for the markets
09-12-2015	Puttalam	Expired pest-attacked rice stock (4 tonnes) was found at Sathosa
23-08-2020	Thissamaharama	There was a high price for rice purchase for the animal feeds than the human consumption.
25-12-2018	Puttalam	Government distributed expired rice stock as a drought relief package
02-01-2017	Whole island	3 years of expired rice stock released for the market, labelled as 'exported rice'
20-03-2020	Vilgamuwa	9,150 kg of unfit rice bought as dry food rations at a cooperative shop destroyed by Wilgamuwa public inspectors

Appendix II

Major upcountry vegetable production (national production and district-wise contribution) from 2015 to 2019.

Year	Vegetables	District production (tonnes)		National production (tonnes)
		Nuwara Eliya	Badulla	
2015	Tomatoes	22,775(29)	13,880(17)	79,553
	Cabbage	61,785(53)	28,116(24)	117,095
	Carrot	48,258(71)	16,369(24)	67,673
	Beans	19,719(30)	25,297(38)	66,163
	Leeks	35,263(85)	4,472(11)	41,434
2016	Tomatoes	33,723(36)	15,073(16)	92,748
	Cabbage	69,704(57)	26,132(21)	123,365
	Carrot	57,974(71)	21,635(26)	82,037
	Beans	32,520(39)	32,315(39)	83,366
	Leeks	55,152(90)	4,580(7)	61,122
2017	Tomatoes	25,881(32)	15,155(19)	80,839
	Cabbage	48,487(49)	26,610(27)	99,466
	Carrot	49,702(69)	19,338(27)	71,607
	Beans	28,152(32)	32,515(37)	87,385
	Leeks	51,195(91)	3,354(6)	56,045
2018	Tomatoes	34,146(34)	19,293(19)	101,404
	Cabbage	54,097(49)	26,933(24)	111,141
	Carrot	51,697(73)	16,405(23)	71,051
	Beans	28,802(34)	34,296(41)	83,966
	Leeks	44,486(87)	5,393(11)	51,330
2019	Tomatoes	17,869(23)	18,003(23)	77,858
	Cabbage	65,917(57)	27,101(23)	116,577
	Carrot	60,577(75)	17,706(22)	80,766
	Beans	24,146(37)	22,719(35)	65,450
	Leeks	27,326(86)	3,159(10)	31,879

Note: Percentage contribution in parentheses.

Source: DCS (2020a).

Appendix III

Major low country vegetable production (national production and district-wise contribution) from 2015 to 2019.

Year	Vegetables	District production			National production
		Hambantota	Anuradhapura	Moneragala	
2015	Ladies finger	5,180 (8)	3,927 (6)	4,930 (7)	66,124
	Brinjals	12,074 (10)	6,913 (10)	8,131 (12)	123,632
	Bitter gourd	5,506 (13)	3,513 (5)	3,226 (5)	43,507
	Red pumpkin	7,854 (7)	18,908 (29)	20,651 (31)	105,877
	Ash plantain	9,703 (11)	3,520 (5)	13,711 (21)	85,085
2016	Ladies finger	6,248 (9)	3,374 (5)	5,123 (8)	66,719
	Brinjals	12,189 (10)	9,142 (14)	11,016 (17)	127,194
	Bitter gourd	5,587 (13)	3,076 (5)	2,964 (4)	42,100
	Red pumpkin	4,952 (5)	19,613 (30)	20,328 (31)	98,303
	Ash plantain	9,538 (12)	3,162 (5)	11,919 (18)	82,226
2017	Ladies finger	4,134 (7)	5,871 (9)	4,244 (6)	61,429
	Brinjals	7,824 (7)	7,912 (12)	8,326 (13)	108,856
	Bitter gourd	5,025 (14)	1,575 (2)	2,155 (3)	37,012
	Red pumpkin	4,380 (5)	15,832 (24)	12,134 (18)	82,934
	Ash plantain	7,831 (11)	4,174 (6)	11,314 (17)	72,702
2018	Ladies finger	4,826 (7)	8,118 (12)	4,829 (7)	68,515
	Brinjals	12,113 (9)	12,012 (18)	8,803 (13)	129,212
	Bitter gourd	6,479 (14)	4,808 (7)	2,712 (4)	47,611
	Red pumpkin	9,085 (7)	38,401 (58)	18,796 (28)	123,261
	Ash plantain	9,736 (12)	4,450 (7)	17,809 (27)	81,200
2019	Ladies finger	5,303 (7)	12,106 (18)	3,847 (6)	72,226
	Brinjals	12,836 (10)	19,450 (29)	7,150 (11)	134,863
	Bitter gourd	6,912 (17)	1,898 (3)	3,557 (5)	40,970
	Red pumpkin	8,544 (9)	23,814 (36)	15,091 (23)	97,473
	Ash plantain	7,663 (12)	5,241 (8)	8,969 (14)	63,460

Note: Percentage contribution in parentheses.

Source: DCS (2020a).

Appendix IV

Summary of priority actions related to agriculture and food security.

Sector	Priority actions
Food security	• Develop tolerant varieties (paddy, OFC, horticulture) and breeds (livestock and poultry) to heat stress, drought and floods and resistant to diseases and pest attacks • Develop and promote water-efficient farming methods • Adjust cropping calendars according to climate forecasts • Develop systems for timely issuing and communicating of climate information to farmers • Develop research institute capacity for conducting research on varieties/breeds and climate resilient farming methods
Water resources	• Develop and implement watershed management plans for critical watershed areas • Increase the efficiency of use and reduce losses of irrigation water • Assess the current practices of water management for climate resilience and identify ways to improve them • Identify and map areas vulnerable to droughts and flood hazards and prepare disaster risk management plans • Design rational intra-basin and trans-basin strategies to harness periodic surpluses of water in storage facilities
Coastal and marine sector	• Implement a continuous programme for monitoring shoreline changes • Develop shoreline management plans including M&E programmes • Study impacts of sea-level rise on coastal habitats over short-, medium- and long-term horizons • Identify, declare, collect information and prepare maps on vulnerable areas to extreme events and inundation • Conduct awareness programmes on sea-level rise and extreme events to coastal communities to empower them when faced by the risks of climate change
Export agriculture sector	• Introduce new cultivars/clones tolerant to heat, drought and flood and resistant to disease and pest attacks • Promote improved nursery and plant management practices and sustainable cropping systems to increase the climate resilience of plantations and crops • Conduct research studies on climate change impacts on export agriculture crops • Identify and collect information on areas most vulnerable to disasters and prepare hazard vulnerability maps for all crops • Develop research institutes' capacity for conducting research on climate change impacts on export agriculture crops

Source: National Climate Change Adaptation Plan 2016-2025.

Appendix V

Annual budgetary allocations for climate change actions.

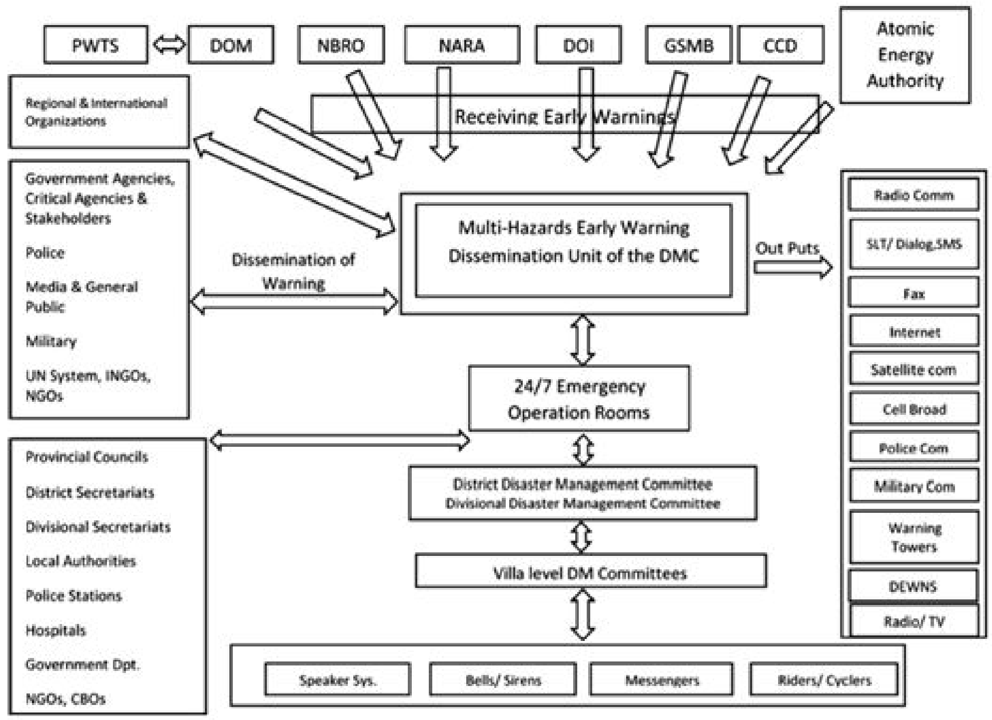
Year	Annual budget allocation (LKR million)					
	Total allocation	Government of Sri Lanka		Donor Agencies		
		Amount	Percentage (%)	Amount	Percentage (%)	Name of the donor
2008	32.62	1.39	4.26	31.23	95.74	UNDP/GEF
2009	16.40	3.00	18.30	13.40	81.70	UNDP/GEF
2010	13.47	2.97	22.00	10.50	78.00	UNDP/GEF
2011	9.33	6.06	64.95	3.27	35.05	UNDP/GEF
2012	23.57	3.80	13.48	19.77	86.52	UNDP/GEF
2013	30.80	12.80	41.56	8.00	25.97	UNDP/GEF
				10.00	32.47	APN*
2014	156.35	5.00	0.64	1.70	1.09	Adaptation Fund
				4.95	3.17	UNEP/ GEF
				27.00	17.28	ADB
				117.70	75.28	WFP/ Adaptation Fund
2015	202.00	2.00	1.00	200.00	99.00	WFP/ Adaptation Fund
2016	428.20	1.50	0.35	426.70	99.65	WFP/ Adaptation Fund
2017	249.85	2.00	0.80	10.00	4.00	UNDP/GEF
				17.85	7.14	WFP/ Adaptation Fund
				220.00	88.05	UNDP/GCF
Total	***1,162.59***	***40.52***	***3.49***	***1,122.07***	***96.51***	

* Asia Pacific Network for Global Change Research.

Source: Hewawasam and Matsui (2019).

Appendix VI

Multi-hazard warning dissemination system.



Source: Hippola et al. (2018).

NBRO: National Building Research Organization; NARA: National Aquatic Research Agency; DOI: Department of Irrigation; GSMB: Geological Survey and Mines Bureau; DMC: Disaster Management Center; SLT: Sri Lanka Telecom; DM: Disaster Management.

Appendix VII

Policies, plans and legislation related to disaster management and disaster risk reduction.

Policy/planning documents/legislations	Date of publication	Description
National Disaster Management Policy (SLNDMP)	2010 (revised 2014)	This policy is organized under five cross cutting principles, namely: Multi-dimensional, collective responsibility, equity, diversity and inclusion, transparency and accountability, and best fit of best practice. Policy is to be reviewed every five years or after a major disaster event, and should be updated to meet emerging needs [10]
National Disaster Management Plan (NDMP)	2013-2017	Incorporates all aspect such as: Institutionally mandated and institutional development, hazard, vulnerability and risk assessment, multi-hazard early warning systems, disaster preparedness and response planning, disaster mitigation, and integration into development planning [11]
Comprehensive Disaster Management Plan (CDMP)	2014-2018	Main objective is to set up legal and institutional systems, prepare vulnerable communities for disasters, and enhance efforts to minimize disaster risks [6]
National Emergency Operations Plan (NEOP)	Draft available and dated 2016.	Provides the guidelines for emergency preparedness in Sri Lanka. The NEOP is under MDM review prior to submission to the Cabinet for approval [12]
Disaster Management Act No. 13 (DMA)	13 May 2005	The DMA is based on a National Disaster Management Bill submitted to Parliament in 2003. This act governs the functions of the National Council for Disaster Management (NCDM) and the DMC. Also, the DMA authorizes the President to declare a 'State of Disaster' in the event of an existing or an impending disaster which cannot be counteracted with resources normally available to the administration. The Act mandates the formulation of key framework documents including the SLNDMP, NDMP and NEOP by the Council [13]
Ministry of Finance and Planning – Budget Circulars No. 152 (I) (II) and (III)	No. 152 (I) – 4 July 2013 No. 152 (II) – 26 December 2014 No.152 (III) – 29 December 2014	These circulars govern the distribution of relief (emergency relief and rehabilitation) by the NDSRC (through the MDM) and relevant line ministries.

Source: Siriwardana et al. (2018).

Appendix VIII

Profile of peri-urban agriculture in Colombo city region

A farmer survey was conducted in August 2020 in three DS divisions in Colombo District namely Kaduwela, Homagama and Seethawaka. The sample size was 111 farmers which included 38 leafy vegetable farmers, 34 home gardeners, 25 paddy farmers and 14 coconut farmers.

Most home gardeners, vegetable farmers, were female while paddy and coconut farmers were male. More than 80% of farmers owned their farmland. Home gardens cultivate on average 12.5 perches and vegetable farmer have an average size farm of approximately 100 perches. Paddy and coconut farmers have an average sized farm of about 1 acre.

About 60% of farmers cultivate on a full-time basis. This is because home gardeners are mainly housewives.

More than half of home gardeners and paddy farmers only consume their produce and do not sell any. About 83% of vegetable farmers sell surplus production. Of the coconut farmers about 60% both consume and sell the surplus. About 50% of vegetable farmers sell their produce to local markets. Coconut farmers sell to private buyers and wholesalers. Home gardeners sell most often to periodic markets (*pola)* or local shops, and paddy farmers most commonly sell directly to nearby households.

The average annual revenue from sale of produce is LKR 30,000, 230,000, 57,000 and 185,000 from home gardens, leafy vegetable, paddy rice and coconuts respectively. There is a paucity of studies on leafy vegetable production and marketing which significantly contributes to micronutrient intake in the Colombo city region.

Source: Dominish, E., Hettiarachchi, K., Samarkoon, D., Esham, M., Winterford, K. and Jacobs, B., (2020). *Social and market research on organic waste value chains in Sri Lanka.* Report prepared by the Institute for Sustainable Futures at the University of Technology Sydney, Janathakshan (GTE) Ltd and Sabaragamuwa University of Sri Lanka.