INITIATIVE ON
Fruit and Vegetables for Sustainable Healthy Diets

Opportunities for and Constraints to Safe and Sustainable Vegetable Production in Sri Lanka

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Summary

Sri Lanka is blessed with ideal conditions for cultivating a wide variety of fruits and vegetables. The country has around 80 varieties produced in different agroecological zones. There are several government and private organizations supporting vegetable farmers and farmers are organized into formally registered organizations. However, the average consumption of fruits and vegetables in Sri Lanka is around 150 g per day and per capita consumption is approximately 112 g per day, which is 50% lower than the World Health Organization (WHO) recommendations (SAARC 2017). For a healthy and prosperous nation, the production and consumption of fruits and vegetables are important.

Our research set out to identify opportunities and barriers for sustainable and year-round vegetable production. The findings are based on two multistakeholder consultations, a gendered field survey conducted in 18 villages through separate women and men focus group discussions (FGDs), key informant interviews in Welimada and Balangoda Divisional Secretariat Divisions, and a comprehensive literature review. The study focused on upcountry temperate zone vegetables.

We found that the main constraints for safe, sustainable and year-round vegetable production are:

i. mismanagement of inputs
ii. poor soil fertility conditions
iii. poor plant health management
iv. no easily available quality inputs
v. damage caused by wild animals
vi. more frequent extreme climate events
vii. uncertain produce prices and marketing issues
viii. lack of information and gaps in technology transfer
ix. lack of conducive policies to promote vegetable cultivation
x. capacity constraints experienced by farmers and extension officers
xi. pre-harvest and post-harvest practices triggering food waste and losses

In our conclusion, we recommend:

- Capacity building to create awareness and change the attitudes of farmers and extension officers to promote and adopt recommended agricultural practices.
- Introduce integrated plant nutrient management, integrated pest management and integrated disease management to improve soil fertility and plant health.
- Introduce crop zoning to minimize price fluctuations of vegetables caused by gluts and scarcity.
- Provide information to farmers and other stakeholders on recommended practices to be followed in pre- and post-harvest vegetable management.
- Address policy and institutional gaps to encourage safe vegetable cultivation and promote digital technologies to minimize existing information asymmetries and extension gaps.

1. Introduction

Sri Lanka sits just below the southern tip of the Indian subcontinent, with highly favorable conditions for crop cultivation. The mean temperature ranges between 21.1 °C and 31.7 °C. The main cultivation seasons are *Maha* (wet season) from mid-October to February, which receives rainfall from the northeast monsoon and *Yala* (dry season) from May to July, which receives rainfall from the southwest monsoon.

Agriculture has been the mainstay of the economy, employing 27% of the total population, while 70% of the rural population depends on farming as their primary source of income (DOA 2021). Of the total land in Sri Lanka, 44% is used for agriculture (Gamage et al. 2017). Land used for home gardens is 18%, other field crop cultivation is 0.87% and sparsely used croplands are 5%. Most of those involved in agriculture are smallholders and cultivation does not exceed one hectare (Wijerathne and Weerakkody 2017).

The contribution of the agricultural sector (including forestry) to the Gross Domestic Product (GDP) was 6.5% in 2022 (CBSL 2022). The GDP contribution from the cultivation of fruits and vegetables was 0.8% and 0.9% (DOA 2021). Fruit and vegetable cultivation has been recognized as a potential avenue for diversifying and commercializing smallholder farming in Sri Lanka (Esham and Usami 2006). Sri Lanka produces approximately 710,000 tons of vegetables and approximately 540,000 tons of fruits annually (EDB 2022). However, the vegetable market has many particularities because the products are perishable (Udari et al. 2021).

Vegetables provide essential nutrients and safeguard human health (e.g., vitamins, minerals, phytochemical compounds, dietary fiber and antioxidants). The World Health Organization (WHO) recommends consuming 400 grams of fruits and vegetables daily to have a healthy life and protect against many chronic and non-communicable diseases. However, the average consumption of fruits and vegetables in Sri Lanka is around 150 grams/day. If we consider vegetables alone, per capita consumption is around 112 grams/day, 50% lower than the WHO recommendation (SAARC 2017).

The yields of the major vegetables produced in Sri Lanka are three times lower than in the United States and two times lower than in Japan (FAO 2017). All major commercial vegetable cropping systems in the country predominantly follow commercial or conventional production, which is comparatively unsustainable compared to traditional cropping systems (Weerakkody et al. 2000; Suriyagoda et al. 2012). Conventional systems are intensive and exhaustive because of the high use of chemical inputs and the overuse of natural resources. The growing population and decreasing arable land resulting from rapid urbanization have put immense pressure on the supply of vegetables in Sri Lanka. Therefore, there is a need for continuous production of high-quality vegetables throughout the year for domestic and export markets (Balasooriya et al. 2005). It is essential to double vegetable production to meet the growing demand and meet the recommended per capita vegetable intake with minimum impacts on the environment and food safety (Weerakkody and Mawalagedara 2020).

The CGIAR Initiative on Fruit and Vegetables for Sustainable Healthy Diets (FRESH) is designed to address this challenge, starting from consumers and working back through the food system to increase fruit and vegetable intake for multiple impacts—improving diet quality, nutrition and health while improving livelihoods, empowering women and youth and mitigating negative environmental impacts. The project comprises six work packages that aim to design, test, and scale end-to-end approaches to sustainably increase fruit and vegetable production and consumption. This report is prepared under Work Package 3, which focuses on enhancing the availability of vegetables through sustainable diversification and intensification.

The FRESH Initiative aims to establish two agroecological vegetable production hubs for participatory technological development and the delivery of suitable technologies, one in Boralanda Agrarian Service Division in Welimada Divisional Secretariat Division (non-seasonal for continuous vegetable cultivation system in sloping lands of the upcountry) and another in Dahamanna Agrarian Service Division in Balangoda Divisional Secretariat division rice-based seasonal vegetable cultivation (Figure 1).

2. Methods and Objectives

The study aimed to identify opportunities and barriers for sustainable and year-round vegetable production, focusing on 'upcountry' vegetables. The project adopted multiple methods to collect data and information. Two multistakeholder workshops were conducted to gather information and understand the different perspectives and issues associated with vegetable cultivation. Participants came from the government, private sector (e.g., agrochemicals, seeds, machinery suppliers, credit providers and biopesticide manufacturers and distributors), academia, farmers, representatives of farmer organizations and vegetable collectors and transporters. A gender-based field survey was conducted in 18 villages through focus group discussions (FGDs) and key informant interviews (KIIs) in Welimada and Balangoda Divisional Secretariat Divisions. The FGDs used semi-structured questionnaires focused on obtaining insights relevant to the specific context of the groups. The opinions of the FGD participants were converted to shared opinions of the group. The primary data collected was supplemented by secondary data and a literature review. This report presents the analysis and outcome of the data and information collected.

3. Agroecological Conditions of the Study Areas

Boralanda belongs to the IU3 agroecological zone in the intermediate zone. The area receives an annual rainfall between 1,750 mm and 2,500 mm. The rainfall pattern of the area shows two peaks in monthly rainfall distribution. The most humid month in Boralanda is November, while the lowest humidity levels are recorded in March. The number of rainy days per month is higher than 20, except in January and February, with an average of 297 days of yearly rainfall. The highest and lowest temperatures are 25 °C to 27 °C and 15 °C to 19 °C.

The area experiences heavy winds from May to September. Slightly higher wind speeds were recorded in November, December, and January. The primary soil type is red-yellow podzolic soil and the terrain can be steeply dissected, hilly and rolling.

Vegetable cultivation is the primary livelihood in the area. Farmers cultivate at least three crops per year. Potatoes are an indispensable crop for most farmers from June to September due to their assured market and high return. Temperate vegetables are the most popular crops cultivated throughout the year. The priority vegetables are green beans (pole beans), carrots, radishes, cabbage and tomatoes. Farmers also cultivate knol khol (Kohlrabi), capsicum and leeks. Suriyagoda et al. (2012) reported similar observations that the main vegetable crops in open-field cultivation of central highland vegetable farming systems are beans, cabbage, carrots, knol khol, beetroot, leeks, radishes and tomatoes. Some farmers cultivate tropical crops such as brinjal and chili. There is a well-established middleman system as an intermediary in collecting, transporting and marketing the vegetables to the wholesale market. Two leading supermarket chains in the country also maintain a vegetable collection center.

Dahamanna is in the intermediate zone under the agroecological zones of IM2a and IM2b. The area receives an annual rainfall of between 1,750 mm and 2,500 mm. The rainfall pattern shows two peaks in rainfall distribution. The average highest and lowest temperatures are 32 °C and 25 °C. Wind speed increases from June to August and farmers use different agronomic practices to protect their crops from strong winds. The main soil types of the area are reddish brown earths and immature brown loam soils. The terrain is hilly and rolling.

Vegetable production in paddy fields is common in the Dahamanna area during the dry season from May to August. Rice cultivation is the main livelihood activity during the wet season. The most popular vegetable crops have been green beans and tomatoes. Farmers are reluctant to diversify to other vegetables because of their long experience with these crops and a high market demand. However, some farmers are cultivating other crops, such as bitter gourd (*Momordica charantia*), yard-long beans (*Vigna unguiculata spp.*), brinjal (*Solanum melongena*), okra (*Abelmoschus esculentus*) and chili (*Capsicum annum*). The suitability to the environment determines the crop selection, market demand, market price, return on investment and farmers' experience cultivating the crop.

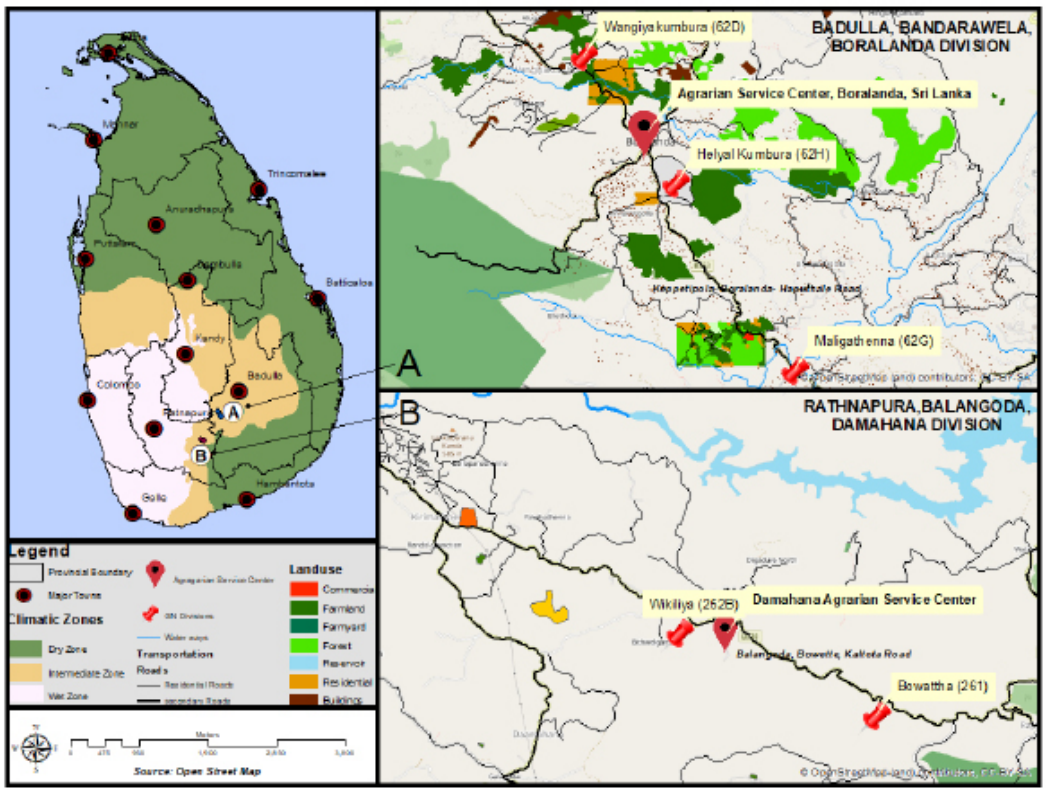

FIGURE 1. Location of the study area.

Source: Map prepared by Dushya Ramamoorthi (IWMI).

4. Vegetable Cultivation in Sri Lanka: Opportunities

Vegetables are the most dominant horticultural crops in Sri Lanka. The vegetable subsector, next to rice, is most important in the non-plantation agricultural sector. The vegetable subsector is a key segment of the food sector, contributing to the country's economy and providing employment for the rural poor (Nuskiya 2019).

Sri Lanka is blessed with ideal conditions to cultivate a wide variety of fruits and vegetables. Given the range of climatic conditions, the country has around 80 varieties cultivated in different agroecological zones (EDB 2022). These can be broadly grouped into 'upcountry' vegetables (mainly temperate vegetables) cultivated at higher elevations (>900 meters) and low-country vegetables (mainly tropical vegetables) commonly cultivated at low (<300 meters) and mid-elevations (300 to 900 meters). The higher elevation of the middle and upcountry regions is climatically cool and have suitable conditions for the cultivation of temperate crops such as carrots, leeks, cabbage, Chinese cabbage, cauliflower, salad leaves, beetroots, beans, bell peppers, tomatoes, cherry tomatoes and zucchini. Low country areas are suitable for various tropical vegetables ranging from green chilis, pumpkins, different types of gourds, brinjal, okra, long beans, cucumbers and gherkins. The main vegetable production areas are illustrated in Figure 2.

Suriyagoda et al. (2012) found that central highland vegetable farmers practice three to four crop cycles per year without a fallow period. About 90% of farmers in Badulla and Kandy districts cultivate rice during the wet season. However, the cultivation area is limited to fulfilling household rice requirements, and the rest of the land is used for vegetable cultivation, given the higher return of vegetable farming (Champika 2016).

According to data published by the Department of Census and Statistics, overall vegetable production in 2019–2020 was 605,295 tons in the wet season and 562,640 tons in the dry season. Due to the bimodal rainfall pattern that prevails in the country, vegetable production follows a seasonal production pattern. Production is high from February to March and September to October and low from June to July

and November to December. This seasonality in production is the main cause of price fluctuations. A significant feature of the country's dietary habit is the consumption of potatoes, roots and tuber crops and yams, as well as the use of many kinds of dry pulses (lentils, mung beans and cowpeas) and tropical fruits (*Artocarpus heterophyllus, Artocarpus altilis*) are cooked as curries (Perera 1990).

The country is divided into three main climatic zones: wet, intermediate and dry, depending on the mean annual rainfall. The west zone of the country has an area of 1.53 million hectares (Mha) that receives a yearly average rainfall of >2,500 mm. The intermediate zone consists of a land area of 4.17 Mha that receives rainfall of 1,750 mm to 2,500 mm. The dry zone receives a rainfall of <1,750 mm per year and has a land area of 0.8 Mha (Weerakkody 2004). These three major climatic zones are divided into 46 agroecological regions based on elevation, rainfall, temperature and soil type. The rainfall distribution has a distinct bimodal pattern. Rainfall in the wet zone is adequate for year-round cultivation but not enough for cultivation in intermediate and dry zones during the dry seasons (Perera 1990). Farmers in the dry and intermediate zones mostly choose to grow vegetables in the dry season in the paddy fields (ranging from 0.2 ha to 0.8 ha) if supplementary irrigation is available (Weerakkody 2004). Intensive cultivation of leafy vegetables (*keerakotu*) is concentrated near Colombo and its suburbs as peri-urban production systems (Weerakkody and Mawalagedara 2020).

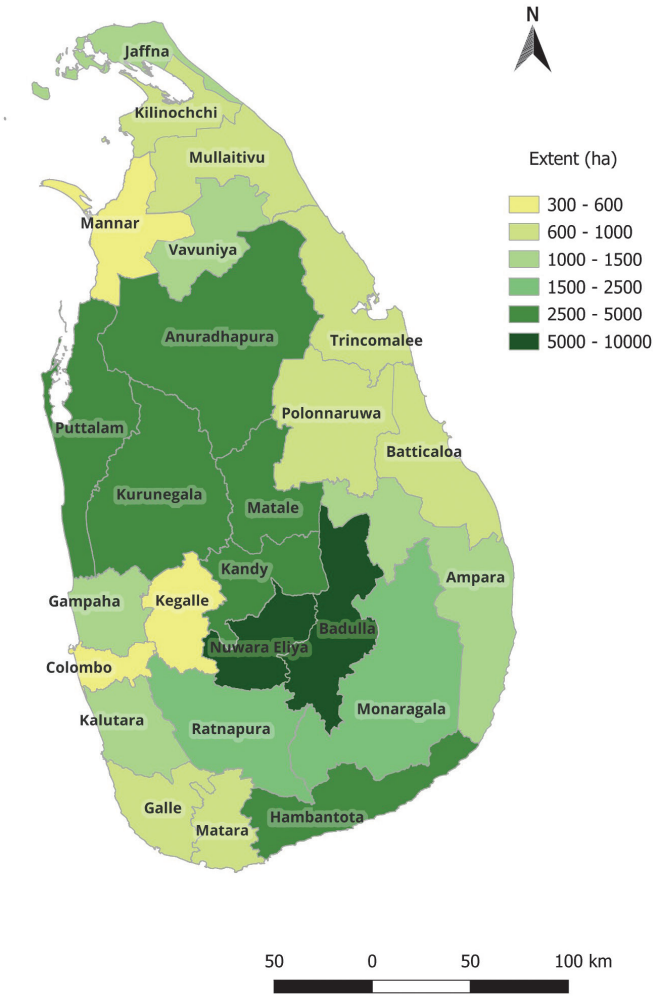

FIGURE 2. Vegetable production areas by extent.
Source: DOA 2022.

Note: Map prepared by Lahiru Madhushanka of IWMI using the area cultivation data under beans, tomato, carrot, cabbage, snake gourd, bitter gourd, luffa, capsicum, brinjal and okra published in DOA (2022).

Vegetables are one of the main crops in organic agriculture. In 2019, 2,338 organic farmers in Sri Lanka produced tea, spices, coconut-based products, vegetables and fruits, coffee and cocoa using organic agriculture methods (Weerahewa et al. 2021). The primary use of organic farming methods is in home gardening and smallholder farming (Weerakkody and Mawalagedara 2020). Official statistics released by Organic International for 2019 show that the area under organic farming in Sri Lanka was 70,436 ha, equivalent to 2.5% of its total agricultural land (Weerahewa et al. 2021).

According to qualitative survey findings, 94% of the FGD participants said the soil in their villages is 'suitable' to 'highly suitable' for vegetable cultivation. Three cultivation methods were identified in the upcountry: single cropping, mixed cropping and multicropping. The method varies from farmer to farmer and from location to location. Single cropping dominates at 50%, followed by mixed cropping and multicropping. Farmers' preference to undertake single cropping is associated with convenience and habits. At the same time, minimization of risk and maximum use of the land are the main two factors for adopting mixed cropping (Nuskiya 2019). Multiple cropping is primarily driven by market demand and water availability during different periods of the year. Crops for a particular season are selected by farmers primarily based on the climatic requirements of the crop. In some areas, interseason cultivation is practiced with short-term crops such as radishes (*Raphanus raphanistrum* sub sp. *sativus*), lettuce (*Lactuca sativa*) and knol khol, taking advantage of residual moisture in suitable lands.

Field-level officers in the study areas said that nearly 10% of farmers in this area practice climate-controlled agriculture, at least to a small extent, to tap high-end markets, producing high-value vegetable crops for year-round supply. Most structures are single-span polytunnels with soft plastic roofing and walls clad with insect-proof nets. Chinese vegetables such as pakchoi, cabbage, salad cucumbers, celery and kale and other high-value vegetables such as bell peppers, beef tomatoes, capsicum, Iceberg lettuce and some herbs are popular under protected agriculture systems (Table 1).

TABLE 1. Extent of cultivated production and productivity of major vegetable crops in Sri Lanka (2020).

Crop	Annual extent (ha)	Annual production (tons)	Avg. yield (tons/ha)
Green bean	7,830	82,973	10.60
Beetroot	2,192	36,262	16.54
Cabbage	4,562	125,746	27.57
Carrot	3,924	90,225	23.00
Knol khol	1,488	17,045	11.45
Leeks	2,319	35,695	15.39
Radish	2,876	55,773	19.39
Tomato	6,569	90,507	13.78
Ash pumpkin	701	11,425	16.30
Okra	8,090	81,444	10.07
Bitter gourd	4,101	47,632	11.61
Brinjal	11,109	141,882	12.77
Capsicum	3,699	31,509	8.52
Cucumber	2,687	38,676	14.39
Red pumpkin	7,741	113,322	14.64
Snake gourd	2,650	32,868	12.40
Luffa	4,231	45,945	10.86

Source: Department of Census and Statistics 2021.

4.1 Institutions and Support Services

The study area has several service providers for vegetable farmers representing government and private organizations. The major government organizations in the area are the Department of Agriculture, Agrarian Development Centers under the Department of Agrarian Development, Irrigation Department, Divisional Secretariat offices, Provincial Department of Agriculture Regional Agriculture Research and Development Center at Bandarawela and Agriculture in-service training Institute at Rajawaka, Balangoda. The Department of Agriculture plays an important role in developing and disseminating new technologies for vegetable cultivation. It provides extension services through Agriculture Instructors, Monitoring Officers, Subject Matter Officers, and Technical Assistants. The department also organizes training and awareness programs for farmers on various aspects of vegetable cultivation, including soil and plant health, safe use of agrochemicals and good agricultural practices (GAP).

Development Officers and Agriculture Research and Production Assistants are grassroots-level officers attached to the Agrarian Development Centers. They are pivotal in distributing subsidized fertilizers, organic inputs, seeds, planting materials and facilitating government support services.

The Divisional Secretariat Division is responsible for holding a monthly Divisional Agriculture Development Committee meeting to address issues related to seasonal cultivation. The committee discusses cultivation planning, formulating seasonal targets, preparing a road map to achieve the targets, conducting training programs for farmers and officers, facilitating the supply of agricultural inputs, crop damage estimations, issuing permits for tube wells, and providing disaster relief and agriculture insurance. Any major issues that cannot be addressed within the committee are referred to the District Agriculture Development Committee, chaired by the District Secretary.

Several private companies are also involved in vegetable cultivation input supplies, including seeds, fertilizers and agrochemicals. According to the survey, almost 100% of farmers depend on private sector organizations for their seeds and agrochemical requirements. In comparison, 10 to 12% depend on government organizations and the private sector. CIC Holdings Plc., Hayleys, Baurs, Brown and Company, and Lanchem are some of the main private sector actors supplying seeds, fertilizers, agrochemicals and other tools and machinery.

Farmers are organized into registered farmer organizations (24 registered farmer organizations in Boralanda and 17 in Dahamanna). Most are functional and are mainly responsible for maintaining irrigation infrastructure and sharing available water resources among farmers.

Figures 3 and 4 illustrate vegetable marketing channels in both the Boralanda and Dahamanna areas. Farmers in the Boralanda area can access vegetable collection centers operated by two major supermarket chains. However, supermarket chains do not collect vegetables in Balangoda due to the seasonal nature of the supply under the rice-based farming system. In addition, Dedicated Economic Centers in Bandarawela and Keppetipola are accessible from Boralanda.

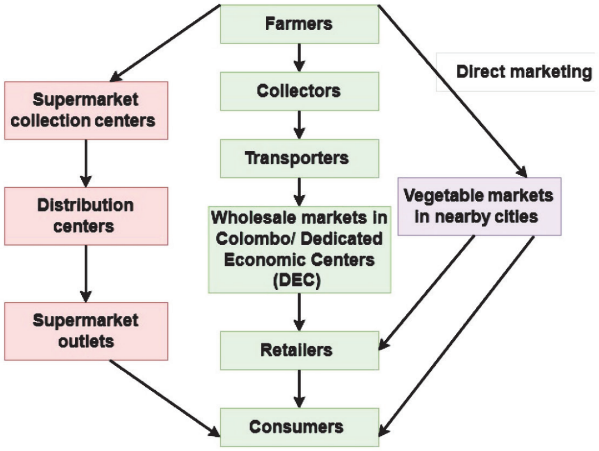

FIGURE 3. Output marketing channel in Boralanda.

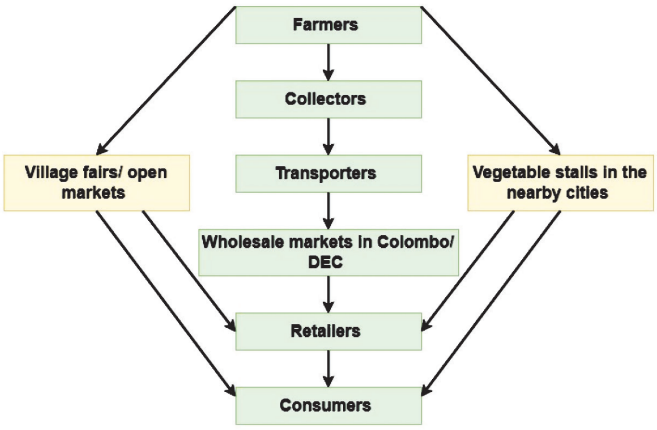

FIGURE 4. Output marketing channel in Dahamanna.

Source: Authors' creation.

5. Major Constraints in Vegetable Production

The two major constraints for safe, sustainable and year-round vegetable production under the conventional production systems are production barriers (e.g., high cost of inputs and services, poor quality of inputs, water shortages, lack of capital or credit, labor shortages and threats from wild animals and pests) and constraints related to marketing and post-harvest practices (e.g., price fluctuations, the dominance of intermediaries, high transport costs, long supply chains and high post-harvest losses). Correctly identifying production system constraints is vital to formulating technical solutions to address the problems. The major constraints are discussed below.

5.1 Poor Soil Fertility Condition

Vegetable farming in the study area is on sloping land and is mainly done by smallholders (Table 2). Weerakkody (2004) indicated that the average plot size is small (0.2 to 0.4 ha) and the land has been under continuous cultivation of annual crops with intensive labor, using organic and inorganic fertilizers and the application of elevated levels of pesticides. Dissanayake et al. (2016) pointed out the practice of overdosing on agrochemicals in upcountry vegetable farming systems.

Monoculture without soil mulches exposes much of the soil surface to the external environment. Survey findings show that about 70% of farmers do not use mulch to conserve soil and moisture due to a lack of awareness and the additional cost incurred by adding mulch. Cultivating tubers and root crops such as potatoes, carrots, radish and knol khol needs continuous soil disturbance in the sloping land terrain under the intense monsoonal rains, causing heavy soil erosion and fertility loss. Most farmers think they can get the best out of the soil by preparing it to a fine tilt and earthing like inter-cultivation practices. FGD respondents (44%) said that soil acidity and alkalinity are problems for most farmers in their villages, while it was reported as a problem for some or a few farmers in 25% of the study villages.

About 83% of the FGD respondents believe most farmers in their villages apply some organic manure. Poultry manure is the main organic manure used by vegetable farmers. Wijewardena (2000) found that the application of poultry manure with chemical fertilizers is popular in the upcountry intermediate zone (10 to 15 tons/ha), whereas cow dung application is popular in the upcountry wet zone (20 to 30 tons/ha). Major reasons for the low use of organic manures as perceived by farmers are high cost, low availability, preference to use inorganic fertilizers and low quality of organic manures. Poor organic matter content in the soil, poor soil biological environment, low pH and groundwater pollution result from long-term unsustainable use of agricultural inputs used in vegetable cultivation.

According to the FGDs, most farmers in 72% of the study villages have adopted some soil conservation measures such as terracing and drain construction and some farmers in another 19% of the study villages. However, soil erosion is causing soil fertility problems for most farmers, as expressed by 64% of the FGD participants. In comparison, it is a problem for a few farmers in 36% of the villages, indicating the insufficiency of the current level of soil conservation practices. Vegetable cultivation under different land tenure agreements, without land ownership, negatively affects investment in soil conservation measures.

The Department of Agriculture and some private companies are promoting in situ soil testing to provide more accurate fertilizer recommendations. However, soil testing practices are not popular among farmers due to a lack of knowledge of testing procedures and poor attitudes toward soil testing and fertility management. Current practice is such that the farmers decide on fertilizer dosages with no basis. Integrated plant nutrient management (IPNM) is an approach to efficiently providing essential plant nutrients, including micronutrients while ensuring soil fertility. Some IPNM components include soil testing for macronutrients, soil pH and EC level. Others include organic matter content, selection of land and crops based on suitability traits, minimum tillage, especially on sloping land, incorporating organic fertilizers, soil pH remediation, improved fertilizer use efficiency by moisture management, adjustment of soil pH, split doses and selecting slow releasing fertilizers and practicing cropping systems such as intercropping, mixed cropping and crop rotations.

TABLE 2. The average landholding size in the study areas.

Average land size (acres)	% of responses (N=36)
0.25–0.5	44
0.5–0.75	33
> 0.75	22

Source: Survey data, 2023.

Note: Responses from the focus group discussions.

5.2 Pest and Disease Management

According to field officers, heavy doses of nitrogen fertilizers have made plants more succulent and easily susceptible to pests and diseases. Some major pests are white flies, leaf miners, caterpillars, tomato fruit borers, thrips and aphids. Some of these insects also act as virus vectors. Adverse weather conditions, such as heavy rains and high temperatures that prevail during the cultivation period create a conducive environment for various fungal and bacterial diseases. The major pests and diseases, as prioritized by farmers in the study areas, are given in Table 3. In terms of pest and disease management, lack of awareness of pests, diseases, and the correct treatment methods are the main problems experienced by most farmers.

The problems experienced by farmers in managing pests and diseases are illustrated in Figure 5. Most farmers and field officers admitted that farmers usually consult with traders or fellow farmers to resolve most of their pest and disease problems. According to farmers, the main reason is that traders provide quick solutions rather than consulting extension staff or waiting for lab test reports. Farmers have paid little or no attention to application frequencies, correct dosage or health and safety indications.

Field officers emphasized the consequences of poor identification of pests and diseases and the inappropriate use of chemicals or mixtures to control pests and diseases without understanding the toxicity levels and health hazards that have aggravated outbreaks by building up resistance to many control measures and eliminating natural enemies and pollinators. All participants of the FGDs perceived that measures taken to reduce pest attacks in their cultivation would positively contribute to vegetable production in their villages.

TABLE 3. Major pests and diseases of the selected vegetable crops as prioritized by farmers.

Level of importance	Beans	Tomatoes	Carrots	Cabbage	Long beans
Pests					
1st most Important	White fly	Fruit borer	Slugs	Caterpillar	Aphids
2nd most important	Pod borer	Fruit fly	Aphids	White fly	Pod borer
3rd most Important	Leaf miner	Aphids	Coccinella larvae	White fly	Thrips
Diseases					
1st most Important	Rust	Late blight	Blight	Rust	Blight
2nd most important	Bean mosaic	Damping off	Soft rot	Club root	Rust
3rd most Important	Anthracnose	Bacteria wilt	Mildew	Black rot	Mosaic

Source: Survey data, 2023.

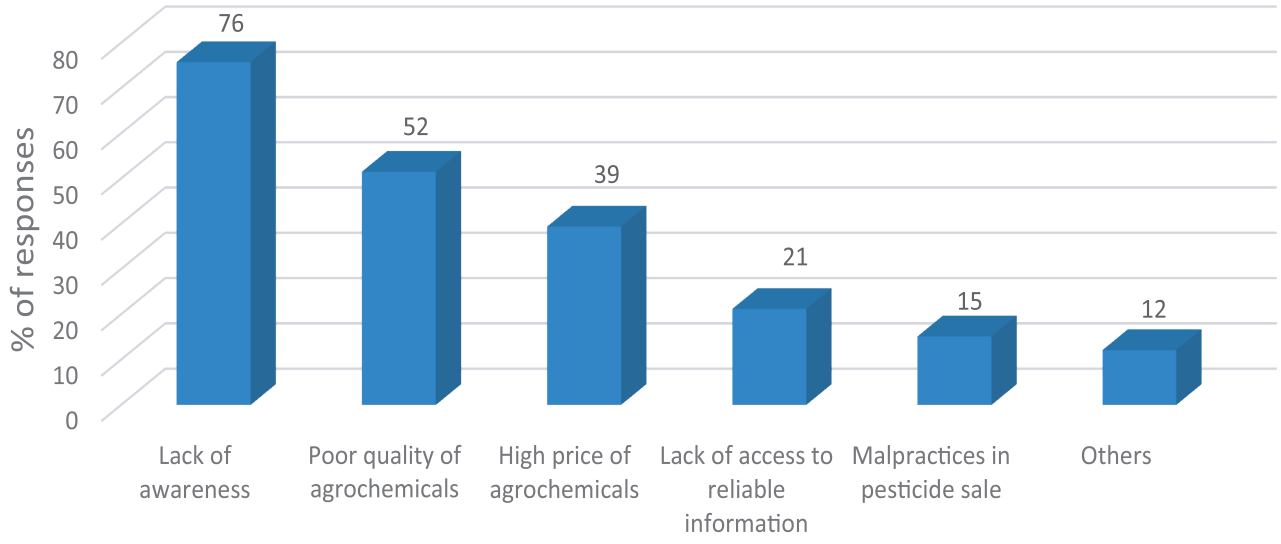

FIGURE 5. Problems experienced by farmers in pest and disease management.
Source: Survey data, 2023.

5.3 Mismanagement of Inputs

The area's vegetable farmers depend heavily on inorganic fertilizers and agrochemicals to manage plant health and increase crop productivity. The main challenge is that farmers do not follow recommendations in applying fertilizers and chemicals, for example, determining dosage, selecting the appropriate chemicals, time of application, frequency and application method. Current practice is generally based on the farmer's judgment or the opinion of fellow farmers or chemical traders. The fertilizer amounts applied are much higher than those in other regions of the country and higher than the Department of Agriculture recommendations (almost double or triple). Overuse, misuse and abuse of agrochemicals in vegetable cultivation have been reported in many studies (Weerakkody 2004; Padmajani et al. 2014; Jayasooriya and Aheeyar 2016; MOA 2016; Gunaruwan 2019). A significant increase in pesticide use in upcountry vegetable growing areas was also reported by Sumudumali et al. (2021)

Overuse of fertilizers and chemicals causes high levels of pesticide residues and heavy metals in the soil and vegetables. Premarathna et al. (2010) reported elevated levels of Cd, Ni, Cu, Pb and Zn in the topsoil of upcountry vegetable growing areas, while in some areas, the level of Cd exceeds maximum acceptable

limits. The concentration of heavy metals in the soils was significantly correlated with the number of years under cultivation. Pesticide residue analysis conducted for cabbage, capsicum and tomatoes in the market or wholesale dealers shows the levels exceed the European Union maximum residue levels (Lakshani et al. 2017).

Mismanagement of agrochemicals is one of the challenges associated with sustainable and safe vegetable production and a waste of resources while causing irreversible environmental degradation. The misuse and overuse of synthetic chemicals and the consequent pollution of land, water and air threaten the existence of endangered species and the balance of natural ecosystems (Suriyagoda et al. 2012).

5.4 Unavailability of Quality Inputs on Time and in Adequate Quantities

The private sector dominates the input market for vegetable cultivation and transactions with farmers are mainly made on an immediate cash payment basis (Mubarak 2019). The COVID-19 pandemic, the economic crisis of 2021–2022 and the import ban imposed on synthetic fertilizers and agrochemicals in April 2021 created scarcity of key inputs at the right time and required quantities. This hurt vegetable production in the area. Difficulties related to the acquisition of inputs (fertilizer, soil conditioners, plant nutrients, seeds, planting materials, chemicals and pesticides) are linked to cumbersome procedures or ad-hoc changes in procedures and long delays involved in obtaining inputs, the high cost of inputs and nonavailability of input materials (Gunaruwan 2019).

Most of the upcountry vegetables are cultivated using imported hybrid seeds. The cost of imported seeds, agrochemicals and machinery has increased enormously due to high exchange rates. All FGD participants agreed that the price of quality seeds is unaffordable. The withdrawal of tax relief for imported agricultural tools and equipment is another reason for their price hikes. According to the FGD findings, only 19% of the participants said they always receive quality seeds for cultivation, while 67% responded that they sometimes receive quality seeds. The same responses were received to the question on the availability of quality pesticides. Farmers complained about the lack of uniformity in the quality of the available seeds. About 94% accepted that poor quality seed is one of the reasons causing a loss of yield or leading to poor yield.

Key informants also emphasized that the high cost and unavailability of inputs are the major limitations on vegetable cultivation. The unavailability and scarcity of quality inputs on time have created illegal market channels for input supplies, especially for seeds and chemicals, which could generate harmful consequences in the long term. Due to the high cost of inputs, farmers use unacceptable materials and practices for pest and disease management, which may hinder safe vegetable cultivation and cause health hazards.

The timely availability of biopesticides and biofertilizers in adequate quantities is another input-related barrier hindering safe and sustainable vegetable production. Although there are many organic pesticide producers and suppliers in the country, none are registered with the Registrar of Pesticides or have government-certified products. According to the manufacturers and suppliers, the registration process is too cumbersome. During the registration process, pesticide producers cannot declare a specific amount of active ingredients in organic pesticides because the composition of the ingredients may vary depending on the source of the raw materials used in the manufacturing. The Registrar of Pesticides said that most biopesticide producers fail to submit the necessary documents to proceed with the onsite inspection.

The National Fertilizer Secretariat of the Ministry of Agriculture insisted that standards for organic fertilizers have been declared and, therefore, organic fertilizers should comply with the standards and be registered under the National Fertilizer Secretariat. However, according to Secretariat officials, it has been difficult to monitor and ensure the quality of organic fertilizers due to the large number of

organic fertilizers, the shortage of testing facilities and staff and the lack of accountability of suppliers and producers. Most inorganic input suppliers insist there are no alternatives available for their products. Furthermore, farmers complained that they have recently experienced poor quality of organic and inorganic inputs and high fluctuations in market prices.

Small-scale farms depend mainly on family labor for routine day-to-day operations, but they hire labor based on daily payment for major activities such as land preparation, planting and harvesting. Medium-scale farmers hire labor for most farming operations. Labor shortages and increased wages for hired labor have caused negative impacts on the commercial production of vegetables (male labor is Sri Lankan rupees (LKR) 1,800/day; female labor is LKR 1,200/day).

5.5 Climate Change Issues

According to Gunathilaka and Samarakoon (2022), Sri Lanka is experiencing the consequences of climate change in the form of extreme droughts and intense rainfall events. Vegetable production in the upcountry areas depends on seasonal rainfall, which has been deviating from the normal pattern due to climate change. About 88% and 59% of the farmers said that beans and tomatoes are highly susceptible to drought, while the same crops are highly susceptible to high rainfall events, as declared by 69% and 89% of the farmers. From the village-level FGDs, 78% of villages did not receive normal rainfall during the last three years. The rainfall received was normal for 89% of the villages and less than normal for 6%. Farmers have also experienced slightly increasing trends in temperature. Farmers believe these climatic variations may have some relationship with pest and disease outbreaks, lower productivity, and poor product quality.

5.6 Lack of Information and Gaps in Technology Transfer

Although the country's extension service provides a commendable service to build awareness and farmer capacities, the lack of field extension officers has created a vacuum in effectively providing services to individual farmers. Each extension officer must cover over 3,000 farmers scattered over a large area. Deficiency in the number of extension staff and their expertise has been inherent in Sri Lankan vegetable production (Perera 1990). A study conducted in the Halmillawa area on the rice-based farming system shows that insufficient advisory service hinders the economic and environmental sustainability of this high-potential farming system (Wijerathne and Weerakkody 2017). Extension officers also mentioned not being empowered with the latest techniques to deploy efficient technology transfers. The officers also said that their task of providing extension services is much broader and covers many crops, a barrier to mastering vegetable cultivation. Some farmers rely on their experience and knowledge, while some consult fellow farmers or traders rather than field officers. This attitude is common among farmers cultivating high-value greenhouse vegetables.

5.7 Uncertainty in Produce Prices and Marketing Issues

The study areas are mostly in hilly terrain (generally applicable to areas under upcountry vegetable farming) and access to farms is not always possible by motor vehicle. Therefore, vegetable collectors are often reluctant to visit the field. Most farmers in the area deliver their products to nearby collecting centers or markets located 10 to 30 kilometers away. The transport cost associated with marketing is considerably higher, reducing the farmer's profit margin. When delivering products to a Dedicated Economic Center, farmers must pay 10% of the price as a commission to the agent.

Seasonal gluts and scarcity cause price fluctuations, leading to income uncertainty. Price uncertainty was the main challenge for farmers in vegetable cultivation. No crop zoning could be seen in this vegetable

production system. Officials emphasized that there is a tendency to cultivate the same crop and the same varieties, leading to oversupply and price reductions. Although the government has tried to implement crop zoning, it has failed due to the popularity and profitability of specific crops and the farmers' experience of traditionally cultivating those crops.

There was a significant difference between farm-gate prices and wholesale and retail prices throughout the island for most vegetables, 90% to 130% higher than the farm-gate price (DOA 2021). The farmers do not receive high prices and the absence of assured prices may discourage them from engaging in vegetable farming.

Lack of market information on demand and supply of their products is a major challenge for farmers (Silva 2005). Farmers usually cultivate what they are familiar with without understanding the quantity and time required. In the existing imperfect information context, though buyers could determine the required quantity in advance, there is a mismatch between the demand and supply of vegetables, causing price volatility on the farmer's end. The price farmers receive is sometimes insufficient to cover their production costs (Silva 2005).

5.8 High Post-harvest Losses

Vegetables from upcountry farms must pass through several intermediaries to the consumer. Poor harvesting practices, including packing, handling and transporting cause significant post-harvest losses across the value chain. These factors determine the shelf life and quality of the product. According to one estimate, 20% to 40% of losses occur in the post-harvest chain (Rajapaksha et al. 2021). Most farmers are unaware of the quality attributes of the vegetables they produce except for the maturity at harvest when the product is examined at the point of sale.

Field observations witnessed the harvesting of premature and over-mature vegetables. Causes included farmers matching harvest to high market prices, lack of harvesting labor and bad weather conditions. These practices lead to lower yields, faster deterioration and poor product quality. In addition to adopting a poor maturity index, some of the other practices leading to post-harvest losses are inappropriate packaging (e.g., net bags for beans and poorly constructed wooden boxes for tomatoes), harvesting during the hottest time of day and overloading transport vehicles to save costs are post-harvest losses for which farmers are responsible.

Nevertheless, some farmers transport their products in plastic crates, especially when transporting their crops to a local collection center operated by a supermarket chain. But when they transport over longer distances, they pack their products in polybags to save costs. Farmers are not satisfied with the unhygienic conditions and rough handling at the wholesale markets or economic centers, but they appreciate collection centers managed by high-end supermarket companies.

5.9 Issues Related to Land Ownership

Farmers are predominantly smallholders operating under different tenure arrangements. These may include a mixture of owned, leased, sharecropping, or encroached lands. Land fragmentation has led to smaller vegetable production operations with less individual farm-level diversity. A smaller land area usually results in higher production costs and lower profits. Most farmers will expand their cultivation area or shift their cultivation to more fertile lands if the government can provide new lands. However, the government is not ready to release lands in the area for cultivation as farmers have encroached on government lands and reservations, which are sensitive ecosystems for biodiversity and wildlife and the upcountry region is part of the main watershed of the country.

According to key informants, nearly 30% of seasonal vegetable farmers in the Dahamanna area are tenant farmers without ownership rights to their lands. These farmers are not willing to make any investment in land development, such as establishing soil and moisture conservation measures, protection fences, drip or sprinkler irrigation systems and other infrastructure (e.g., agrochemical storage, insect-proof net) required for GAP that will generate a return in the medium to long term.

5.10 Lack of Conducive Policies

Inconsistent and changing policies, along with the limitations of existing laws and regulations, also create barriers to promoting vegetable cultivation. The government input subsidy policy and the output guarantee price programs are biased toward rice farming, discouraging farmers from growing vegetables, especially in rice-based farming systems. For example, the fertilizer subsidy policy prevailed in the country recently and the latest cash transfer program to purchase fertilizers is limited to rice cultivation and some other selected field crops. According to the Paddy Land Act, paddy lands cannot be converted to other purposes, although some farmers are used to growing vegetables. Crop insurance against climate disasters (e.g., floods, droughts) and wild elephant damage also applies to paddy and some selected crops but not vegetables. Under the current regulations, the compensation to landowners under tenant cultivation is comparatively higher for rice farming than non-rice crops. Therefore, tenant farmers face barriers from landlords to engage in vegetable cultivation in rice-based farming systems, although vegetable farming has a competitive advantage.

The current Pesticide Regulation Act No. 33 of 1980 does not provide guidelines for the registration of biopesticides. It is recommended that the current act be amended to include guidelines and regulations for this purpose. This would enable the local biopesticide industry to meet current requirements (DOA 2020). The absence of a dedicated policy to regulate and set quality standards for biopesticides and biofertilizers is a challenge for producers. The issue was highlighted by manufacturers as the concentration and composition of bio-ingredients vary in different ecologies and types of plant species. The policy may need to consider active ingredients of bioproducts in a range, unlike specific values in inorganic products.

One way to ensure safe vegetable production is to promote organic and GAP-certified vegetable production. However, it was reported that the current organic and GAP certification process takes a long time to obtain. The process is complex, with a cumbersome documentation procedure and is costly. After all the hard work and risks of cultivating safe products, no arrangements are made to receive a premium price for organic and GAP-certified products.

5.11 Damage Caused by Wild Animal Pests

Crops in the area are experiencing severe damage from wild animal pests, especially monkeys, wild boars, peacocks, mouse deer and porcupines. The damage caused by these pests has increased over the years due to the growing animal population and the lack of mechanisms to manage them. Farmers are helpless in controlling them. Indigenous methods such as scarecrows, firecrackers, traps, and air riffles are being used with little positive results. According to the farming community in Boralanda, monkeys seldom damage crops like radish, cabbage and knol khol due to the pungent smell generated by sulfur-containing compounds in Brassicaceae crops and the 'blood' color in beetroots.

6. Barriers to Adopting Recommended Agricultural Practices

Integrated management of vegetable production systems consisting of good agricultural practices offers a proven path to greater resource use efficiency and improved productivity while offering safe food, environmental protection and improved farmer wellbeing. Recommended and safe agricultural practices such as integrated pest management, integrated disease management and integrated plant nutrient management have been promoted by the government and NGOs for many years, but the level of adoption is considerably low in the country (De Costa et al. 2021; Malkanthi et al. 2021; Jayasooriya and Aheeyar 2016; Senanayake and Rathnayaka 2015).

For example, integrated plant nutrient management advocates the balanced use of organic and inorganic fertilizers for sustainable crop production. However, vegetable farmers in the upcountry region apply more than the recommended doses of synthetic fertilizer without adding the recommended amounts of organic fertilizers (Upekshani et al. 2018). The soil fertility in different parts of Sri Lanka varies temporally, spatially and under different crops (Kumaragamage and Indraratne 2011). Therefore, understanding the site-specific fertility status must direct fertilizer and nutrient recommendations.

Soil testing is carried out by the Department of Agriculture, some government research organizations and private sector companies, but their analytical capacity is limited to pH, electrical conductivity and nutrients (Dandeniya and Dharmakeerthi 2020). There is no capacity in these organizations to deliver timely soil test results to farmers if demand is high. The main challenges in integrated plant nutrient management are the low availability and competitive use of organic manure sources and associated high transportation costs, lack of standards for organic fertilizers and labor-intensive application. Other barriers include the lack of farmer knowledge about integrated plant nutrient technologies and the inadequate links and interactions with farmers and extension officers. The government and other organizations should encourage farmers by providing suitable facilities and conducting large-scale demonstrations and training and awareness programs (Gyeltshen and Sharma 2019).

According to the literature, farmer adoption of recommended integrated management practices is hindered by the lack of awareness and technical know-how. For instance, this has been the case for integrated plant management (IPM) (De Costa et al. 2021; Liyanage et al. 2020; Sumudumali et al. 2021; Padmajani et al. 2014; Ahangama and Gilstrap 2007; Jayasooriya and Aheeyar 2016). A study conducted by Liyanage et al. (2020) among vegetable farmers indicated that only 5% are aware of IPM Similarly, Jayasooriya and Aheeyar (2016) found that although the term IPM was familiar to 44% of the surveyed farmers, only 20% had some level of understanding of the technique. Some farmers see IPM as an inefficient crop protection approach and incompatible with current commercial agriculture using high-yielding hybrid seeds (Ahangama and Gilstrap 2007).

In addition to the lack of knowledge of IPM, many other problems have been reported as barriers to the adoption, including high labor requirements, delayed response in controlling pests and diseases, lack of trust in the efficiency of IPM techniques, difficulty in applying the technique to larger operations, high risk associated with the method and the lower effectiveness of applying IPM at individual farm level (Padmajani et al. 2014; Jayasooriya and Aheeyar 2016). It has been reported by De Costa et al. (2021) that the majority of farmers see IPM as an inefficient method of pest and disease control and therefore, they are not willing to adopt it. Farmers also complained about the difficulty in finding plant extracts, which are part of most IPM packages, and the higher opportunity cost in engaging IPM given the requirement of more labor time. Although microbial agents are a component of IPM, field use of such microbial formulations in Sri Lankan agriculture is absent (Ahangama and Gilstrap 2007) or very limited. The weaknesses in national policies for IPM promotion, poor attitudes of farmers and extension officers, insufficient human resources in the current extension system, lack of capacity of extension officers in IPM and lack of resources and institutional support for IPM promotion are also hindering IPM promotion among vegetable farmers. According to Nishantha et al. (2016), the nonavailability of farmer-acceptable, efficient, alternate pest and disease control methods hinders minimizing pesticide use in vegetable cultivation.

The problems associated with the application of IPM, or non-chemical pest control, are primarily related to technical and economic aspects of the techniques, attitudinal and behavioral issues of the farmers and officers and drawbacks related to information dissemination and awareness (Jayasooriya and Aheeyar 2016).

7. Capacity Constraints and Development Programs

7.1 Capacity Assessment

As a first step in assessing capacity needs, we identified and mapped the institutions, agencies and individuals that play a critical role in the vegetable sector of the two regions. The identified institutions and organizations play an important role in developing goals, designing interventions, implementing the recommended technological packages and delivering training programs.

The capacity assessment was conducted through two stakeholder consultation workshops, six focus group discussions and 36 key informant interviews. Customized semi-structured questionnaires guided data collection. A literature review was conducted to collect secondary data and validate and triangulate primary data. Key informants from the government sector representing the Department of Agriculture, Department of Agrarian Development, Divisional Secretariats and universities were interviewed. Interviews representing private sector organizations were also conducted among selected agricultural input suppliers (agrochemical, fertilizer, machinery, seed and greenhouse material suppliers), transporters, collectors and banks. Vegetable farmers in selected areas (Boralanda and Dahamanna), extension officers, and field staff from the private sector were also interviewed to identify capacity constraints and opportunities in vegetable production and marketing.

7.2 Results of the Capacity Assessment

Farmer Organizations

There are 24 registered farmer organizations in Boralanda Agrarian Service Division and only 15 are functioning. The number of registered farmer organizations in the Dahamanna Agrarian Service Division is 17, but only 12 are functioning well. The main factors affecting the functionality of these organizations are poor leadership, low membership, no significant benefits of being a member, and lack of support from authorities. Actively functional organizations in the areas provide credit facilities to members, bulk purchasing of seeds and other inputs, group marketing of agricultural produce, collective action to ensure timely cultivation to optimize resources, sharing irrigation water and maintenance of community infrastructure. However, many farmer organizations are dominated by men, with no arrangements for routine meetings, an absence of a mechanism to review and track progress and without an annual action plan. Sustainability traits such as leadership skills, teamwork, innovative thinking and enthusiasm for organizational progress are lacking. Focus areas for capacity development improvements include:

- Teach agribusiness and entrepreneur skills to farmers through existing extension services that not only empower farmers on technical aspects of crop cultivation but also build entrepreneurial skills.
- Conduct programs to develop leadership and organizational management skills of farmer organization leaders.

Input Suppliers

Private sector organizations dominate the input market, including seeds, fertilizers, agrochemicals, credit labor, equipment, packaging materials and greenhouse materials. The lack of availability of quality material inputs at the correct time in the required quantities has hurt vegetable production in the area. According to a leading agricultural input supplier, the cost of formulation and distribution of fertilizers and agrochemicals is high in complying with government regulations such as import taxes, testing and receiving approval for a new product, sample testing of current products, and lengthy documentation procedures.

Although many biofertilizers and biopesticides suppliers are in the region, none are registered with the Registrar of Pesticides. Suppliers blamed the delays on the registration process, but the Registrar's Office insisted that the delay was due to the inability of suppliers to comply with their recommendations and submit the required documents. The situation has led farmers to depend on inorganic fertilizers and pesticides. Farmers are concerned about the degraded quality of inputs available in the market. The lack of formally approved organic pesticides or the delay in registering organic pesticides should be addressed.

Leading fertilizer supply companies offer an in-situ soil testing service and recommend fertilizer application. Although inaccurate, it is important to understand the soil nutrient status and use fertilizers accordingly. However, less than 20% of farmers take advantage of this service. This service can be used by farmers for effective and efficient management of plant nutrition while minimizing the adverse impact of synthetic fertilizers on human health and the environment.

Agriculture machinery, greenhouse materials and other equipment, such as irrigation accessories and plastic crates are supplied by reputable companies. Water pumps (electric or fuel-operated) are becoming less popular due to their high operational costs. Obtaining power connections to farms in isolated high elevations is also a problem. If solar water pumps can replace these at a comparable cost or on a credit basis, that would be a viable option. Focus areas for capacity development improvements include:

- Create awareness among organic input producers of the required standards and the registration process, testing samples, complying with the standards, completing the required documents, submitting an application, preparing the production facility for inspection, continuous monitoring and testing for quality improvement.
- Improve the collaboration between the private and state sectors to develop and enhance new technologies and train farmers and field officers.

Transporters and Collectors

Farmers, transporters and collectors are important value chain actors responsible for minimizing harvest loss. Lack of knowledge and farmers' concern about pre-harvest factors (harvesting techniques) and post-harvest practices (affecting the post-harvest life and quality) significantly contribute to food losses.

Vegetable collectors include private individuals and high-end chain supermarkets such as Cargills and Keells. Supermarkets have employed trained staff in vegetable collection centers to pay attention to post-harvest practices and ensure vegetable quality. They promote using plastic crates for the transportation of vegetables and have cold storage facilities and refrigerated trucks. However, private collectors are not adopting these recommended practices in handling, packing, transporting, loading, unloading and storing vegetables, thereby causing substantial food losses. The knowledge and concern of collectors, transporters and traders on post-harvest handling of vegetables (e.g., cool room facilities and refrigerated transport) should be improved. Focus areas for capacity development improvements include:

- Educate and train collectors, transporters, and traders on the causes of post-harvest losses and techniques to minimize them.

- Equip collectors, transporters and traders with knowledge of the cost-benefits of post-harvest management.

Farmers

According to key informant interviews, farmers are generally concerned with activities that would maximize profit but are rarely interested in food safety, environmental safety, optimal use of resources and social responsibility. Important entrepreneurial skills such as farm planning, financial management, business development and record keeping are lacking among many farmers. Therefore, most farmers are continuously in subsistence conditions despite hard work, year-round cultivation, good yield and income. Most farmers were unaware of GAP, which is important for safe and sustainable vegetable production. The officers responsible for the GAP certification process admitted that conventional farmers strongly believe that the GAP procedure cannot be adopted under open field cultivation due to the procedures for pest and disease management and maintaining a pre-harvest chemical-free period.

Although many technologies have been developed for safe vegetable production, the rate of farmer adoption is not significant. The gap between the latest available technologies and farmer practices was highlighted. The lack of interest among farmers in new technologies, farmer risk aversion and weaknesses in methods used for technology transfer were reported as reasons for the existing knowledge gap.

Poor farmer knowledge of integrated pest and disease management includes maintaining good field hygiene, the importance of balanced plant nutrition, selection resistant varieties, applying recommended agronomic practices, use of biopesticides and pest repellents, management of natural enemies and use of agrochemicals. Poor knowledge of integrated approaches has led to indiscriminate application of agrochemicals that cause environmental pollution, exposure to pesticide hazards and increased cost of production. The knowledge and skill to maintain good plant health through integrated pest and disease management must be strengthened.

The conventional practice of farmers to ensure plant nutrients is by applying inorganic fertilizers, usually with doses higher than the recommended levels. Many have no understanding or interest in nutrient management, which aims to address the total soil fertility (physical, chemical, biological and hydrological properties) while minimizing land degradation. There is a knowledge and skill gap among many farmers in nutrient management, which is a necessary trait in sustainable vegetable production.

Most farmers in these regions depend on external finance from government banks, private banks, farmer organizations, commission agents and private money lenders to meet the capital cost of cultivation. The existing high cost of production, adverse weather, escalated prices of fertilizer and agrochemicals, increased incidence of pest and disease outbreaks and poor-quality seeds have made farmers reluctant to take the investment risk required for vegetable cultivation. Therefore, farmers must be educated on financial resilience to anticipate financial risk and uncertainty in vegetable production. Focus areas for capacity development improvements include:

- Educate farmers on the efficient use of water resources by increasing awareness of the competing demands for water, irrigation techniques, infrastructure maintenance, the selection of crops, soil and moisture conservation measures.
- Build farmers' knowledge to identify pests and diseases, methods of exclusion and prevention, integrated plant and disease management problems and risk of inappropriate pest and disease management approaches.
- Educate farmers on soil fertility management for quality output and higher productivity, crop selection, cropping systems, agronomic practices that improve plant nutrition, soil testing to recommend correct plant nutrient requirements, soil conservation strategies and integrated plant nutrient management.

- Create awareness of good agricultural practices (GAP) and their benefits and train farmers to comply with GAP recommendations with minimum modifications and investments.
- Train farmers on the best harvesting practices and post-harvest management and the cost-benefit of such practices.
- Educate farmers about emerging digital agricultural technologies to improve access to information on inputs, markets, weather and the latest innovations.
- Assist farmers in improving their entrepreneurial skills for enhanced productivity and wellbeing.

Extension Officers

According to extension officers in the study areas, under the existing arrangements, they are responsible for providing advisory services to farmers on many crops, including paddy, vegetables, other field crops, floricultural crops and home gardening. This restricts opportunities for them to specialize in a particular crop. Although extension officers have general agricultural knowledge, they lack expert knowledge of vegetable cultivation, especially innovations and new technologies. Focus areas for capacity development improvements include:

- Provide training to extension officers to update their knowledge and skills in vegetable production, especially in innovations and the latest technologies.
- Train extension officers on effective methods of technology transfer.

7.3 Prioritized Capacity Development Areas

According to the findings of the capacity assessment, there are several gaps and potential solutions. Table 4 describes the priority capacity development areas identified for different target groups. Table 4 also indicates the capacity development objectives and the key elements suggested for capacity development to achieve the objectives.

TABLE 4. Capacity development objectives of the priority areas.

Prioritized capacity development areas	Capacity development objectives	Key elements	Target groups
Entrepreneurial skills	– To improve financial management skills and knowledge of planning and record keeping for sustainable agricultural enterprises – To improve networking skills with experts, fellow farmers and traders	Budgeting, cost-benefit analysis, business planning, projections, record keeping, networking with fellow farmers, agriculture institutes, experts, field officers, markets and traders	Farmers and extension officers
Soil and plant health management	– To introduce the GAP[a] certification procedures in vegetable production – To assist farmers in fulfilling requirements for GAP certification	Understanding GAP and its benefits, certification procedures, meeting the requirements and the GAP village concept	Farmers and extension officers
Plant health management IDM[b] and IPM[c]	– To improve the knowledge of principles and strategies of IPM and IDM. – To implement I.P.M. and I.D.M. strategies customized for prioritized vegetables	Identification of major pests and diseases, the economic threshold of damage, principles of pests and disease management, cultural, mechanical, physical, chemical, biological control measures and their customized combinations	Farmers and extension officers
Soil fertility management-IPNM[d]	– To improve the knowledge of IPNM. – To implement IPNM strategies customized for prioritized vegetables	Importance of good soil fertility, the role of macro and micronutrients, fertilizers and soil amendments, optimizing input use efficiency, selection of crop/cropping systems, agronomic practices and soil conservation	Farmers and extension officers
Post-harvest management of vegetables	– To improve the knowledge and skills in pre-harvest techniques, vegetable handling, packing and post-harvest techniques to minimize post-harvest losses of priority vegetables. – To improve the knowledge and skills in packaging, transporting and handling techniques to minimize post-harvest losses of priority vegetables	Average post-harvest losses of prioritized vegetables, the importance of post-harvest management, causes of post-harvest losses and cost-benefit analysis	Farmers, collectors and transporters, private sector field-level staff and extension officers
Technology transfer	– To equip field-level officers with the knowledge and skills required for the effective transfer of technology to farmers	Adult learning principles, adult teaching strategies, planning programs with farmers, identifying early adopters of new technology and risk management	Extension officers

Source: Authors' creation.

Note: [a] GAP = good agricultural practices, [b] IDM = integrated disease management, [c] IPM = integrated plant management, [d] IPNM = integrated plant nutrient management.

8. Conclusions and Recommendations

Vegetable production in Sri Lanka, both subsistence and commercial, is done with conventional production methods and technologies. Major causes affecting the productivity and sustainability of vegetable production are the lack of attention to soil fertility, high use of synthetic fertilizers and agrochemicals, weak connection to the extension system and gaps in information and innovations, unplanned cultivation without considering market demand and supply and poor harvesting and post-harvest handling. Therefore, technological innovations to increase productivity, production efficiency, food quality and food safety are vital to address existing production barriers and ensure safe vegetable cultivation.

These recommendations are based on the analysis carried out in the two selected vegetable farming systems.

1. Build capacity and awareness for farmers and extension officers through the relevant authorities, projects and programs on measures to increase water use efficiency, improve soil fertility through soil nutrient management and improve plant health.
2. The government should allocate the necessary funds to build the capacity of extension staff by providing pH and electrical conductivity meters to allow onsite field testing to offer farmers advice on soil amelioration to improve fertilizer use efficiency.
3. Introduce technologies to farmers and extension staff to improve soil fertility by promoting soil and moisture conservation techniques, soil testing to adopt crop and site-specific nutrient management and integrated plant nutrient management.
4. The government should promote digital technologies to minimize information asymmetries and extension gaps and provide farmers with services through existing communication platforms with real-time climate information, agronomic advisories, market price data, links to input suppliers and other support services.
5. Extension service should develop programs to educate farmers and promote techniques on integrated pest and disease management and good agricultural and management practices to develop technological proficiency customized to specific crops and geographies while addressing the hindrances and barriers related to the current agricultural practices and organic product registration and certification process.
6. The DOA should develop and promote climate-tolerant vegetable varieties that are pest and disease-resistant.
7. The DOA should develop crop zoning directed to farmers to minimize market price fluctuations (gluts and scarcity) and generate higher produce prices based on market analysis, choosing reliable short supply chains and group marketing arrangements to address the smallholder issues experienced in collecting and transporting the produce to local and export markets.
8. Work with agro-input value chains (manufacturers and retailers) to make innovations like biofertilizers and biopesticides readily available and establish links for direct sales by farmers to supermarkets, hotels, hostels and export companies.
9. Government agencies enlist academic and private sector actors to teach entrepreneur and leadership skills to farmers and farmer organization leaders.
10. Extension officers to work with academic and private sector actors to educate and train collectors, transporters and traders on the causes of post-harvest losses, techniques to minimize the losses and the cost-benefits of good post-harvest management.

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CGIAR Initiative on Fruit and Vegetables for Sustainable Healthy Diets

The FRESH Initiative aims to use an end-to-end approach to increase fruit and vegetable intake and in turn improve diet quality, nutrition, and health outcomes while also improving livelihoods, empowering women and youth, and mitigating negative environmental impacts**.**

To learn more about this Initiative, please visit
https://www.cgiar.org/initiative/fruit-and-vegetables-for-sustainable-healthy-diets-fresh/

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