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BARRIERS AND DRIVERS FOR ADOPTING THE CHEMICAL LEASING CONCEPT TOWARD SUSTAINABLE VEGETABLE FARMING IN SRI LANKA

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ABSTRACT

The heavy use of synthetic agrochemicals is a common feature of vegetable farming. This excessive use of agrochemicals underlies fundamental problems related to health degradation, higher vegetable production costs, and environmental damage. The Chemical Leasing Concept (CLC) is based on the premise that it can enable users to reduce the costs associated with high chemical use, reduce environmental and health harms, and curb chemical overuse. Thus, the purpose of this study was to identify the barriers and drivers to the adoption of the Chemical Leasing Concept. The study employed a mixed-methods approach, and data were collected from 30 full-time, medium-scale vegetable farmers. The data were analyzed using thematic analysis for qualitative data and the Participatory Ranking Method (PRM) for quantitative data. The findings confirmed that the most significant barriers included: (1) farmers' unawareness of Chemical Leasing, (2) doubt about the practicality of the Chemical Leasing concept, (3) uncertain weather and climate conditions, (4) Chemical Leasing being viewed as a risk, (5) a lack of norms, standards, and frameworks to implement Chemical Leasing, and (6) soil infertility. In contrast, the most significant drivers identified were: (1) saving farmers' time through convenience, (2) providing a solution to agrochemical shortages, (3) avoiding the import and use of inferior agrochemicals, (4) reducing costs and increasing profits, (5) producing healthier products, and (6) access to expert knowledge. Further, awareness campaigns, trust-building initiatives, and financial risk management schemes were recommended to overcome the identified barriers

Keywords: Chemical Leasing, barriers and drivers, sustainable-vegetable-farmers

INTRODUCTION

For the world to achieve its development goals, sustainable and inclusive food systems are essential. Expanding agriculture is one of the best strategies to reduce extreme poverty, increase income equality, and provide food for the estimated 9.7 billion people globally by 2050. Growth in the agricultural sector is more successful than growth in other industries in improving the incomes of the poorest people. Economic growth also depends on agriculture, which in 2018 contributed 4 percent of the global Gross Domestic Product (GDP) and up to 25 percent in some least-developed countries (The World Bank, 2022). According to the Central Bank of Sri Lanka (2021), the agricultural sector, which holds a significant share of the economy of Sri Lanka, makes a substantial contribution of 7.4 percent to the overall national GDP. Traditional agrochemical-based production or conventional agriculture methods that rely heavily on chemical fertilizers, pesticides, and other agrochemicals (Gunarathne & Duminda, 2014) in Sri Lanka are widely used in commercial vegetable cropping systems. Nonetheless, peri-urban, home gardens, and organic farms are becoming more attractive places to practice sustainable vegetable production (Padmajani et al., 2014).

Plantation-based and non-plantation-based agriculture are two types of farming used in Sri Lanka. Tea, rubber, and coconut are all products of plantations. The non-plantation industry comprises field crops, paddy, vegetables, and fruits. After paddy, the vegetable subsector is the most significant. It is further divided into low-country and up-country vegetables. Nuwara Eliya and Badulla districts in Sri Lanka's central highlands serve as the primary regions for vegetable cultivation. The primary vegetables in Sri Lanka are potatoes, leeks, carrots, beets, beans, and cabbage. These vegetables are rich sources of essential vitamins and minerals. They play a crucial role in meeting the nutritional requirements of the Sri Lankan population. More than 70 percent of Sri Lankan consumers' vegetable needs are satisfied by up-country vegetables (Haque et al., 2022; Hassan, 2019). Vegetables are grown in different districts of Sri Lanka, and the Nuwara Eliya District has a special place among them because a large number of vegetables are grown annually in this district, and most of the country's total requirements are fulfilled by farmers of that particular area. Therefore, the Nuwara Eliya district (categorized under the up-country region) was selected for the current study.

The most significant crops in terms of total production are potatoes, cabbage, beans, and carrots. In contrast, the main up-country vegetables in terms of the total area are potatoes (Solanum tuberosum), cabbage (Brassica oleracea), tomatoes (Solanum lycopersicum), beans (Phaseolus vulgaris), carrots (Daucus carota), and radish (Raphanus sativus) (Padmajani et al., 2014). The utilization of agricultural pesticides in Sri Lanka has shown a significant rise in recent decades. The usage of pesticides has experienced significant growth in recent years due to the growing adoption of high-yielding crops and the expansion of irrigation systems. However, the application of agrochemicals was initially slow until it was introduced as a crucial component of the overall set of techniques devised to integrate new crop varieties with high yields. Similar to paddy cultivation in Sri Lanka, it relies primarily on agrochemicals. Additionally, approximately 90 percent of farmers primarily rely on agrochemicals for irrigated market-oriented crops (exotic vegetable crops) and vegetables, except soybeans (Jayakody et al., 2006). Pesticides are now considered essential for vegetable cultivation.

However, unfortunately, pesticide use indiscriminately jeopardizes human health and has detrimental long-term repercussions on the ecology. Therefore, society as a whole must bear the cost of the harm that pesticides create. Up-country vegetable farming is one of the intensive cultivation farming systems that uses a substantial number of pesticides and fertilizers due to the short crop lifespans and excessively humid conditions that facilitate the quick spread of pests and disease (Padmajani et al., 2014). Using

pesticides, encompassing insecticides, fungicides, and herbicides, is sometimes considered indispensable in agriculture. In the complete absence of pesticides, there is a potential for an increase in production costs. The majority of pesticide usage in Sri Lanka is allocated to the cultivation of food crops. Pesticides have been utilized in agricultural practices for an extended period to manage and mitigate the impact of pests, fungi, and weeds on crops and livestock. Pesticide measures possess several advantages over alternative methods such as cultural control practices, including crop rotation (e.g., avoiding the cultivation of the same crop species in successive seasons), physical control methods such as hand-picking of insects in home gardens, and botanical or indigenous pest control methods that utilize plant-based or traditional substances (e.g., neem (Azadirachta indica) extracts and chili–garlic–ginger formulations), because of their convenience, rapid efficacy, and ability to diminish pest populations to low levels effectively. The extensive use of pesticides directly influences human well-being, not only through water source contamination but also due to the occurrence of acute and chronic pesticide poisoning in the environment (Schlosser, 1999).

Since 2006, the United Nations Industrial Development Organization (UNIDO) has promoted the Chemical Leasing Concept within its Cleaner Production Program (Jakl, 2008; Weerakkody et al., 2022). It aligns the rewards for chemical producers and users by transitioning from a traditional seller–buyer relationship to a service relationship. The seller becomes the service provider, while the buyer becomes the consumer. Chemical Leasing is a service-oriented business model that creates an environmental and economic win-win situation for chemical suppliers and consumers (Jakl & Schwager, 2008). Therefore, it is a market-oriented tool with multiple benefits for the parties involved (Maier, 2014). Chemical Leasing represents an innovative concept, particularly in the context of agriculture in Sri Lanka (Weerakkody et al., 2022). Hence, the concept of Chemical Leasing is very new in Sri Lanka, and chemical suppliers should provide a vast amount of support to implement the concept sustainably; otherwise, the concept may fail. Furthermore, farmers must have a solid technical understanding when adopting this unique approach. Farmers fear adopting new changes. People have become accustomed to old farming methods and are less driven to seek fresh and inventive solutions (Weerasinghe, 2022).

Most farmers in the Nuwara Eliya district, mainly, are vegetable producers. In such a context, farmers in the Central Highlands frequently administer higher dosages of agrochemicals to increase yields rather than strictly adhering to the recommended doses and application frequencies suggested in the instructions. Due to their ignorance of the environmental impacts that pesticides have after application, farmers do not consider the repercussions of their decisions. Farmers tend to overdose and apply pesticides more frequently due to the lack of knowledge about the pesticide's biochemical processes and a desire to stop the spread of diseases (Watawala et al., 2010). However, this overuse can result in enormous costs for farmers. Multiple studies have revealed that the application of fertilizers in Central Highland vegetable farming exceeded the recommended levels (Wijewardhana, 2001a, 2001b, 2001c; Wijewardhana et al., 2001; Wijewardhana & Amarasiri, 1993, 1997). According to Ariyapala and Nissanka (2006), the overutilization of agrochemical fertilizers not only results in higher production costs but also has a detrimental impact on the natural environment.

Vegetables differ from most perennial crops in that they require only a short time in the field, yet produce large amounts of biomass. As a result, most farmers in the up-country use large quantities of insecticides and fertilizers (Hassan, 2019). Considering all these factors, the current research investigated the barriers and drivers among full-time medium-scale up-country vegetable farmers in the Nuwara Eliya District to adopt the Chemical Leasing Concept, which has the potential to contribute to sustainability and environmental protection, as well as to increase user and supplier profits while reducing costs and chemical consumption (UNIDO, 2021). Hence, this research study addressed the following questions to identify barriers and drivers for implementing the Chemical Leasing Concept, especially in the up-

country area in Sri Lanka. According to Padmajani et al. (2014), the cultivation of vegetables in the up-country region is widely favored by farmers in the Nuwara Eliya, Badulla, Kandy, and Matale districts, located in the central highlands of Sri Lanka. However, the researcher only focused on vegetable farmers in the Nuwara Eliya District, one of the significant districts cultivating vegetables in the up-country region.

LITERATURE REVIEW

Global Fresh Vegetable Production

Vegetables refer to plant portions that can be consumed raw or cooked. They are essential providers of dietary fiber, potassium, other minerals, and vitamins A and C. Eating more fruits and vegetables can reduce a person's risk of many chronic diseases. According to Statista (2023b), global fresh vegetable production was 1,154.6 million metric tons in 2021. The world's vegetable crop was predominantly produced in Asia in 2021, accounting for 903.19 million metric tons of fresh vegetables, representing 78.22 percent of the global fresh vegetable production. When considering the Asian region in 2021, mainland China produced more than 600.01 million metric tons of fresh vegetables. It was the top producer in the world, while India produced 137.99 million metric tons of fresh vegetables and was the second-highest producer globally. The United States produced 27.92 million metric tons of fresh vegetables in 2021, ranking third globally (Statista, 2023a). In 2019, the globe produced about 1.1 billion tons of vegetables, a relatively stable figure compared to previous years. More than 79 percent of the world's supply was produced in Asia (Hortidaily, 2021). Nowadays, Sri Lanka's vegetable yields are 10–70 percent lower than they could be in countries like Japan, the United States, and India (Weerakkody & Mawalagedera, 2020).

Vegetable Production in Sri Lanka

The vegetable cultivation in Sri Lanka is characterized by its intensive nature and significant commercialization (Upekshani et al., 2018). The total land area dedicated to vegetable farming in Sri Lanka in 2015 amounted to 90,518 hectares, with around 35 percent of this area being in the up-country region (Anon, 2016). The total annual production of vegetables was 998,491 tons in 2017, including up-country and low-country vegetable production. Total up-country vegetable production consisted of beans, cabbage, radish, carrot, knol-khol, leeks, and tomatoes in 2017. Total low-country vegetable production consisted of ash plantain, pumpkin, lady's finger, bitter gourd, cucumber, red pumpkin, brinjal, capsicum, snake gourd, and luffa in 2017 (Hamangoda & Pushpakumari, 2018). Therefore, a high level of intensity and commercialization characterizes vegetable cultivation in the up-country region of Sri Lanka. This is primarily because the income generated from vegetable production exceeds that of other agricultural practices (Wijewardhana, 2000).

Up-country Vegetable Farming

Vegetable production is one of Sri Lanka's primary agricultural industries. The varied agroecological regions of Sri Lanka can support a variety of vegetable crop species. Vegetables are constantly needed in the local market since Sri Lankans consider them essential to their daily diet. The Nuwara Eliya District is a notable area and one of the prominent growing locations for up-country vegetables, which contribute significantly to the country's vegetable production (Dharmasena, 2017). According to the overall output, white potatoes, cabbage, beans, and carrots are the most significant crops (Padmajani et al., 2014). Further, according to Weerakkody and Mawalagedera (2020), most agricultural practices in Sri Lanka are based on commercial vegetable cultivation systems and rely on conventional production techniques

that involve agrochemicals. Additionally, according to Upatissa et al. (2021), the Nuwara Eliya district in Sri Lanka is widely recognized as the primary region for up-country vegetable cultivation.

Impact of Agrochemicals Usage in Vegetable Cultivation

Agrochemicals have a significant role in modern high-intensity agriculture. A wide range of techniques and numerous products are employed in agricultural systems to maximize crop yield. Agrochemicals utilized to improve soil quality and enhance crop output encompass a range of substances, such as insecticides, liming and acidifying agents, synthetic fertilizers, hormones, as well as soil conditioners. The term "agrochemicals," sometimes known as "agrichemicals," typically encompasses a wide variety of chemical substances, specifically pesticides such as herbicides, fungicides, and insecticides. The utilization of agrochemicals has been identified as essential for maximizing agricultural productivity (Shahid & Khan, 2022). In addition, chemical fertilizers, which are a type of agrochemical, are produced through industrial synthesis using predetermined quantities of components such as nitrogen, phosphorus, and potassium. However, excessive or improper usage of these fertilizers can contaminate the air, water, and soil (Youssef & Eissa, 2014).

The inappropriate handling of agrochemicals is one of the many risks connected to agricultural activities that impact farmers, their food, and the environment. Both aquatic and terrestrial ecosystems are impacted by the deterioration of the quality of groundwater used for human consumption (Nikolaidis et al., 2008). Pesticides have become widespread due to their high ability to kill pests and rapid action against insect populations in various ecological conditions. However, serious concerns exist about how the rising use of pesticides may impact production costs, human health, the environment, and the quality of agricultural product (Mohottige et al., 2002). Nevertheless, the overutilization of these agrochemicals in an irresponsible and unregulated manner has been found to result in ecological (Koli et al., 2019) and environmental harm (Cederberg et al., 2019), which includes alterations in the populations of significant native microorganisms in the soil (Mandal et al., 2020).

A notable example of the ecological impact of agrochemical use is the pollution of Lake Gregory in the Nuwara Eliya District. This contamination is attributed to multiple factors, particularly the influx of agrochemicals from surrounding agricultural lands. The lake's catchment area is characterized by intensive vegetable cultivation and a high population density, resulting in runoff that carries agricultural chemicals, urban wastewater, and sediments into the lake (Amarathunga et al., 2010). Furthermore, pesticide residues are no longer confined to farming areas but have been detected in water, air, and various vegetables and fruits, posing serious environmental and public health concerns (Ali et al., 2021). Human exposure to pesticides has been linked to immunological dysfunction, endocrine disruption, reproductive disorders, cancer, and cardiovascular effects (Sabarwal et al., 2018).

Sustainable Agriculture

According to Carter and Liane Easton (2011), "there is an increase in education and awareness relating to the science behind climate change, and the business effects that environmental and social sustainability could have on business". Nasr (2010) recommended advocating sustainable manufacturing practices to preserve the Earth's scarce and valuable natural resources. Since the release of the Brundtland Report in 1987, the concept of sustainable agriculture has become increasingly prominent, along with the broader notion of sustainable development (Tait & Morris, 2000). Sustainable agriculture was defined by the U.S. Congress (1990) as an "integrated system of plant and animal production practices having a site-specific application that will, over the long term: (a) satisfy human food and fiber needs; (b) enhance environmental quality; (c) make efficient use of non-renewable resources and on-farm resources and

integrate appropriate natural biological cycles and controls; (d) sustain the economic viability of farm operations; and (e) enhance the quality of life for farmers and society as a whole."

Reganold et al. (1990) stated that to achieve sustainability within a farm, it should produce sufficient, high-quality food while protecting resources and the environment. It emphasizes economic profitability, reduces dependence on purchased inputs like fertilizers, and prioritizes natural processes and renewable resources available within the farm. Additionally, according to MacRae et al. (1989), sustainable agriculture consists of management practices that align with natural processes to preserve resources, minimize waste and environmental consequences, eliminate issues, and foster the resilience, self-regulation, evolution, and continuing productivity of agroecosystems, ultimately serving the purpose of nourishing all stakeholders involved. To address resource efficiency and climate challenges, businesses need resilient, adaptable strategies that support sustainable operations and long-term profitability. The Chemical Leasing concept is recommended as an effective approach to reduce environmental impacts from chemical use in vegetable (Green Industry Platform, 2021).

Chemical Leasing Concept (CLC)

The origins of the chemical leasing concept may be dated back to the work of Jakl et al. (2004), who were the first to provide a theoretical framework for this concept. Their publication presented assumptions regarding the possible economic and environmental advantages associated with the Chemical Leasing concept. This concept was introduced, among others, during the International Conference on Experiences and Perspectives of Service-oriented Strategies in the Chemicals Industry and Related Areas. The feedback received from the presentation proved beneficial in enhancing the framework for implementing the Chemical Leasing concept. Specifically, it significantly contributed to improving the legal framework governing collaboration and the legal aspects of the chemical's life cycle (Jakl, 2008). There were a total of six Chemical Leasing pilot projects conducted in Austria, which served as the primary focus of the study. The knowledge and insights gained from the Austrian pilot projects were then utilized to allow the worldwide extension and implementation of the underlying concept. In 2007, UNIDO initiated collaboration with its NCPCs to conduct pilot projects in Egypt, Mexico, and Russia. These efforts were supported by former consultants who had previously worked on Austrian pilot projects.

Following the initial projects' achievements, UNIDO decided to expand and enhance the promotion and internationalization of the Chemical Leasing concept. Consequently, subsequent initiatives were undertaken in Sri Lanka, Serbia, and Colombia. The creation of a UNIDO Chemical Leasing Toolkit has been informed by the experience gained in seven pilot countries. This toolkit aims to offer a structured methodology for the adoption of Chemical Leasing business models at the organizational level (Maier, 2014). The Chemical Leasing concept has been created as a business model to enhance the chemical industry's contribution to sustainability. Conventional sales business models in the chemical industry are still insufficient to motivate minimizing excessive consumption or to facilitate the spread of knowledge regarding the optimal utilization of chemicals or implement efficient recycling practices (Ohl & Moser, 2007). The Chemical Leasing concept (CLC) was proposed by Jakl and Schwager (2008), and it can effectively support and enhance the adoption of a Cleaner Production (CP) approach (Lozano et al., 2014). This CP approach involves applying an integrated environmental strategy that focuses on preventing pollution across processes, products, and services. By integrating Chemical Leasing principles, organizations can achieve higher operational efficiency while mitigating risks to both human health and the environment (UNEP, 2006; UNIDO, 2002).

Drives for Adopting the Chemical Leasing Concept by Vegetable Farmers

Despite recent calls for the conservation of the environment, many countries currently rely heavily on agrochemicals for agricultural production (Weerakkody et al., 2022). However, according to the vast majority of studies, farmers use sustainable practices to safeguard the soil, reduce ground and surface water pollution, produce high-quality goods with fewer chemical inputs, and reduce health risks for farming families and livestock (Drost et al., 2022). The following drivers (Table 1) of the Chemical Leasing concept were identified through a thorough literature review.

Table 1

Drivers for Adopting the Chemical Leasing Concept

Drivers	Source
Environmental friendliness – Reduce the usage of agrochemicals effectively and be eco-friendly	Guha et al., (2020); Jin et al., (2015); Singh et al., (2020); Wijewardhana et al., (2001)
Environmental friendliness – CLC is an effective business model that motivates collaborative efforts to reduce, reuse, and substitute chemicals.	Maier (2014)
Lifecycle aspect - CLC initiates cross-sectoral, cross-product integration that transcends eco-efficiency and lifecycle management integrity.	Maier (2014)
Circular business model - CLC offers economic incentives for reducing, reusing, and recycling substances.	Maier (2014)
Knowledge and awareness increment - CLC increases global development goals by facilitating the transfer of knowledge and technology to developing and emerging nations.	German Federal Environment Agency (2010)
Competitiveness - Chemical Leasing is competitive.	Beyer (2008)
Hope for quality requirements - High-quality requirements are essential to successful Chemical Leasing business models.	UNIDO (2011)
Economic factors – CLC helps bring down costs.	Beyer (2008); German Federal Environment Agency (2010)
Economic factors – CLC adds value, and the provider and the customer benefit financially.	Jakl & Schwager (2008); Maier (2014)
Expert knowledge gaining - Chemical Leasing offers specialized knowledge to mitigate resistance at the managerial level.	Maier (2014)
Social reputation increment - Both parties can benefit from an innovative and positive public image by operating within the CLC.	Joas (2008)
New market opportunities and new technology - Economic potential (opportunity to enter fresh markets, open to global competitiveness), research and development potential (accessibility and relevance of new technologies and substances).	German Federal Environment Agency (2010)

Barriers to Adopting the Chemical Leasing Concept by Vegetable Farmers

The Chemical Leasing concept is a relatively novel business model; therefore, the anticipated constraints can play a significant role when implemented. In some instances, an incentive for a producer or supplier of chemicals can be a constraint for a user (e.g., closer connections between supplier and customer) or vice versa (German Federal Environment Agency, 2010). The existing literature identifies the following barriers (Table 2) to adopting the Chemical Leasing concept.

Table 2

Barriers to adopting the Chemical Leasing Concept

Barriers	Source
Lack of policy, framework, and regulatory issues - Strong regulations are required to function as a framework requirement for CLC to ensure an acceptable degree of risk.	Maier (2014)
Lack of policy and framework, and regulatory issues - The liability concerns are a restraint.	German Federal Environment Agency (2010)
Lack of policy, framework, and regulatory issues - The lack of accountability within local governments.	Su et al. (2013)
Lack of Awareness – CLC is still relatively novel, leading to a lack of awareness.	Weerakkody et al. (2022)
Resistance to change - The end user is reluctant to change.	Valerio et al. (2008); Maier (2014)
Economic Barriers - Lack of financial support mechanisms and tax incentives.	Liu et al., (2017)
Economic Barriers - The high transaction cost for farmers.	World Economic Forum (2022)
Lack of Trust - The most significant Barrier is the partners' lack of trust.	German Federal Environment Agency, 2010)
Social Barriers - the perception that conventional farmers who utilize organic methods are 'bad farmers' because they can see more weeds in their fields.	Hale (2021)
Lack of Technical Skills - Insufficient technical support and training hinder CLC.	de Jesus & Mendonça, (2018); German Federal Environment Agency (2010)
Uncertain weather and climate conditions – *"Due to climate change, the time pattern of rains in the Nuwara Eliya District has changed,"* as mentioned by Mr. Chandrasiri.	Chandrasiri (Personal communication, October 02, 2023)
Uncertain weather and climate conditions – Commonly, in Nuwara Eliya, the determining element for applying pesticides is the climate.	Dilhani et al. (2015)

METHODOLOGY

Since both qualitative and quantitative data were employed, this research was designed as a mixed-methods study with an exploratory orientation. The study population comprised full-time medium-scale vegetable farmers in the Nuwara Eliya district. According to the Office of the Assistant Director of Agriculture (2023), farmers who cultivate vegetables as their primary source of income and operate landholdings ranging from one to five acres are classified as full-time medium-scale farmers. Although the Chemical Leasing concept can be implemented by both large enterprises and small and medium-sized organizations across various industries (Schwager, 2008), officials from the Office of the Assistant Director of Agriculture indicated that the concept is more suitable for medium-scale vegetable farmers in the Nuwara Eliya district due to their operational scale and resource management practices.

Sample adequacy was determined based on the principle of data saturation commonly applied in qualitative research (Guest et al., 2006), where approximately 20–30 interviews are considered sufficient to capture key themes. Accordingly, thirty full-time medium-scale vegetable farmers were selected using a non-probabilistic purposive sampling approach based on their accessibility to the study population. The sample size achieved data saturation, and the same participants were retained for the Participative Ranking Method to ensure consistency between the qualitative and quantitative components of the study.

Data were collected through face-to-face interviews using both open-ended and closed-ended questions. During the interviews, farmers were directly asked about the barriers and drivers influencing the adoption of the Chemical Leasing concept, and their explanations regarding these factors were recorded for analysis, as well as practices regarding agrochemical application (adherence to prescribed limits or overdosing), and their prior awareness of the CLC. Their responses were recorded to capture contextual insights and support subsequent thematic analysis.

Data Analysis

Data analysis in this mixed-methods study comprised two phases. First, qualitative data were analyzed using an inductive thematic analysis. Interview transcripts were manually coded without specialized software due to the manageable size of the dataset. Themes were identified through repeated reading and systematic coding. To reduce interviewer bias, a semi-structured interview guide was consistently applied, and reflective notes were maintained. Ethical considerations were ensured through informed consent, voluntary participation, and the protection of participant confidentiality.

Second, a quantitative element was incorporated using the PRM, implemented with Microsoft Excel Professional Plus 2021. According to Ager et al. (2010), PRM is a participatory mixed-methods approach that engages respondents in identifying, ranking, and prioritizing issues based on their perceived importance. The method combines qualitative insights with quantitative ranking, allowing rich, context-specific data to be systematically compared across participants.

In this study, the themes derived from the thematic analysis formed the basis for the PRM exercise. The same set of farmers were asked to rank the identified barriers and drivers according to their relative importance. In the PRM, barriers and drivers identified through thematic analysis were ranked by each farmer from the most to the least important. The individual ranking values assigned by the 30 participants were summed separately for each barrier and driver and then divided by 30 to obtain an average ranking score. This procedure was applied to all 16 identified barriers and 14 drivers. The resulting average scores were subsequently arranged in descending order to determine their relative priority. This approach ensured that no thematic findings were omitted or merged arbitrarily; rather, all themes identified through qualitative analysis were retained and subsequently quantified through participatory ranking. As the PRM yields ordinal data from a non-probabilistic sample and aims to prioritize perceived importance rather than infer population-level differences, inferential statistical tests and confidence intervals were not applied.

ANALYSIS AND RESULTS

Thematic Analysis of Barriers & Drivers to adopt the Chemical Leasing Concept by Farmers

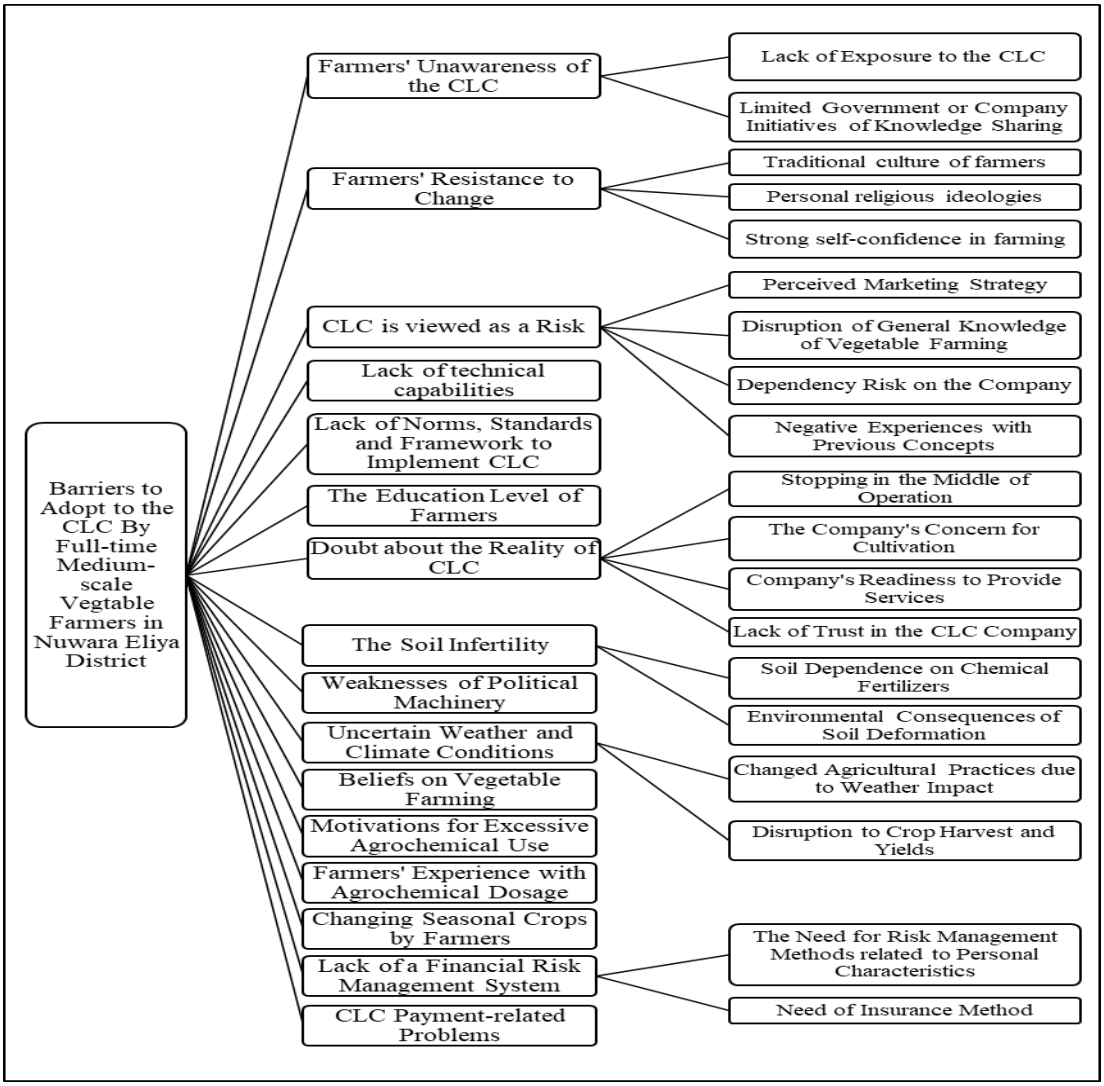
Thematic analysis provided an in-depth understanding of the barriers and drivers influencing the adoption of the Chemical Leasing concept. Qualitative data from semi-structured interviews were analyzed inductively following the six-stage thematic analysis framework proposed by Braun and Clarke (2006), encompassing data familiarization, coding, theme development, review, and final interpretation (Proudfoot, 2023).

Barriers to Adopting the Chemical Leasing Concept by Farmers in Nuwara Eliya District

Figure 1 is a thematic map of barriers to farmers adopting the Chemical Leasing concept. As shown in the thematic map of barriers, the researchers identified 16 main barriers and 19 sub-barriers to adopting the CLC by full-time medium-scale vegetable farmers in the Nuwara Eliya District.

Figure 1

Barriers to Adopting the Chemical Leasing Concept among Farmers in Nuwara Eliya District



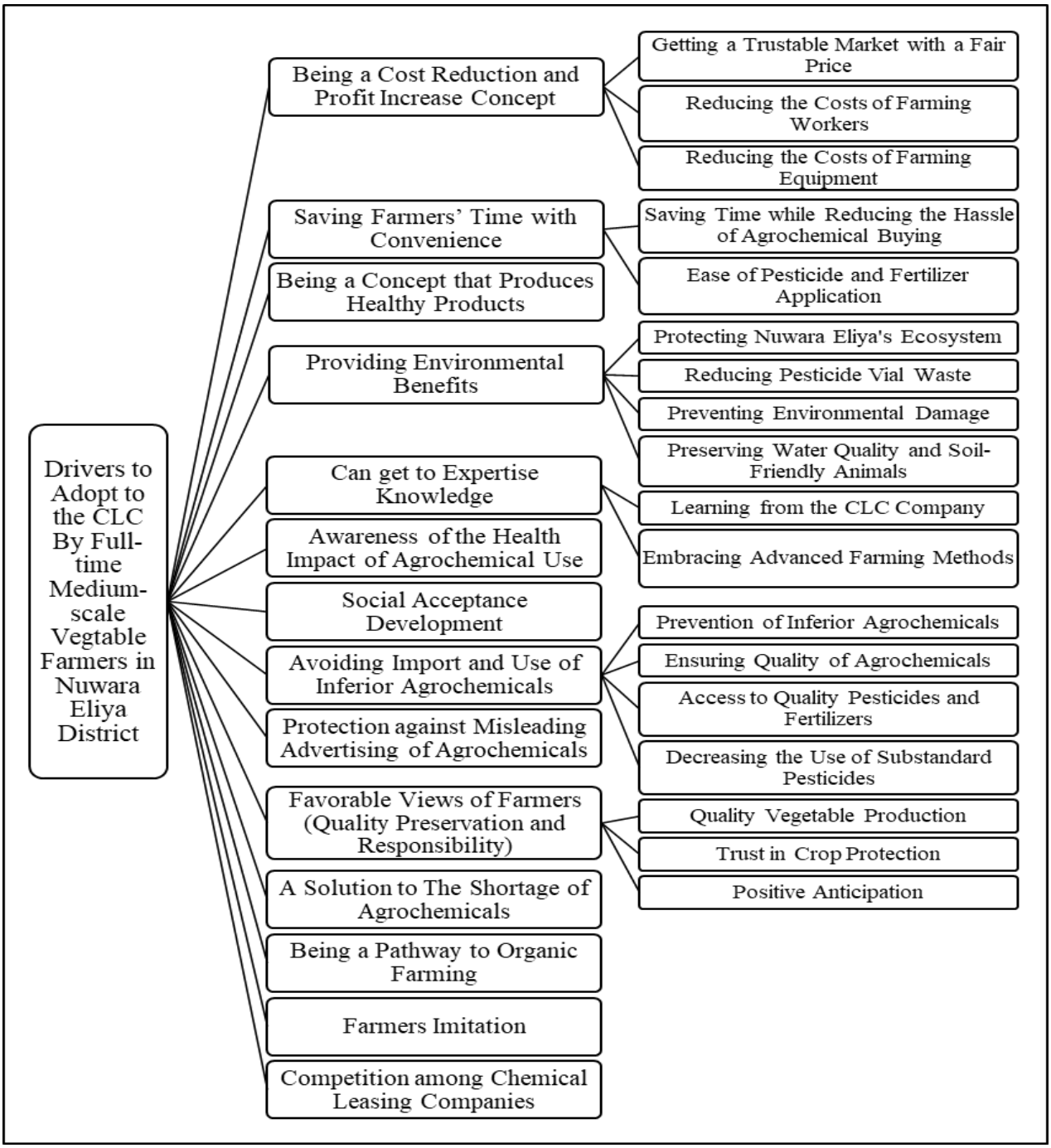
Source: Researchers' own work

Drivers to Adopt the Chemical Leasing Concept by Farmers in Nuwara Eliya District

Figure 2 is a thematic map of drivers for farmers to adopt the Chemical Leasing concept. As shown in the thematic map of drivers, the researchers identified 14 main themes of drivers and 18 sub-themes of drivers to adopt the CLC by full-time medium-scale vegetable farmers in the Nuwara Eliya District.

Figure 2

Drivers for Adopting Chemical Leasing Concept among Farmers in the Nuwara Eliya District



Source: Researchers' own work

Participative Ranking Method (PRM) Analysis of Barriers and Drivers

Here, the PRM was used to determine the relative priority of the barriers and drivers identified through thematic analysis. Each of the 30 farmers ranked the identified barriers and drivers from the most significant to the least significant based on their perceived importance. For barriers, the individual ranking values assigned by all participants were summed separately for each barrier and divided by 30 to calculate an average ranking score. This procedure was applied to all 16 barriers included in the ranking exercise. The resulting average scores were then arranged in descending order to establish the overall priority of barriers, as presented in Table 4. The same procedure was followed to prioritize the drivers. The ranking values assigned by the 30 farmers for each driver were summed separately and divided by 30 to obtain an average ranking score. This process was applied to all 14 drivers, and the resulting scores were ordered from highest to lowest priority, as shown in Table 5.

Table 4

Ranking of Barriers to Adopting the Chemical Leasing Concept by Farmers

Barrier Code	Barrier	Average	Rank (Descending)
B_01	Farmers' unawareness of the CLC	11.17	1
B_02	Farmers' resistance to change	8.80	11
B_03	The chemical Leasing concept is viewed as a risk	10.00	4
B_04	Lack of technical capabilities	9.70	7
B_05	Lack of norms, standards, and a framework to implement the chemical leasing concept	9.87	5
B_06	The education level of farmers	9.60	9
B_07	Doubt about the reality of CLC	10.40	2
B_08	Soil infertility	9.73	6
B_09	Weaknesses of political machinery	9.20	10
B_10	Uncertain weather and climate conditions	10.23	3
B_11	Beliefs in vegetable farming	6.80	12
B_12	Motivations for excessive agrochemical use	9.67	8
B_13	Farmers' experience with excess agrochemical dosage	5.50	14
B_14	Changing seasonal crops by farmers	4.57	16
B_15	Lack of a financial risk management system	6.03	13
B_16	CLC payment-related problems	4.73	15

Source: Researchers' own work

Although Weerasinghe (2022) identified the unawareness of the Chemical Leasing concept basics as the most critical barrier considered by farmers in adopting the Chemical Leasing concept in the Badulla District, this is not different in the Nuwara Eliya District, where the same situation is observed, with "farmers' unawareness of the Chemical Leasing concept" ranked first as the most significant barrier (Table 4). However, in the Badulla District, aversion to novel advancements is the second most crucial barrier considered by farmers in adopting the Chemical Leasing concept (Weerasinghe, 2022), which differs from the farmers in the Nuwara Eliya District, who ranked the barrier "doubt about the reality of the Chemical Leasing concept" as second.

In addition, this study identified several context-specific barriers unique to the Nuwara Eliya District, including soil infertility, weaknesses in political machinery, uncertain weather and climatic conditions, beliefs about vegetable farming, and motivations for excessive agrochemical use. These locally embedded factors reflect the distinct agro-ecological and socio-economic conditions of the district and further complicate the adoption of the Chemical Leasing Concept (CLC) among full-time medium-scale vegetable farmers.

Table 5

Ranking of Drivers to Adopt the Chemical Leasing Concept by Farmers

Driver Code	Driver	Average	Rank (Descending)
D_01	Being a cost reduction and profit increase concept	8.93	4
D_02	Saving farmers' time with convenience	10.90	1
D_03	Being a concept that produces healthy products	8.13	5
D_04	Providing environmental benefits	7.13	7
D_05	Can get expert knowledge	7.73	6
D_06	Awareness of the health impact of agrochemical use	6.70	10
D_07	Social acceptance development	5.87	12
D_08	Avoiding import and use of inferior agrochemicals	9.60	3
D_09	Protection against misleading advertising of agrochemicals	6.87	9
D_10	Favorable views of farmers (quality preservation and responsibility	6.20	11
D_11	A solution to the shortage of agrochemicals and fertilizers	9.87	2
D_12	Being a pathway to organic farming	7.00	8
D_13	Competition among chemical leasing companies	4.73	14
D_14	Imitating farmers	5.33	13

Source: Researchers' own work

Although Weerasinghe (2022) identified the cost-saving aspect as the most critical driver for adopting the Chemical Leasing concept in the Badulla District, it differs in the Nuwara Eliya District, where the "time-saving" driver ranked first as the most important driver, as mentioned in Table 5. However, in the Badulla District, the time-saving aspect is the second most important driver considered by farmers for adopting the Chemical Leasing concept (Weerasinghe, 2022), which differs from the farmers in the Nuwara Eliya District, who ranked the driver "a solution to the shortage of agrochemicals" as second.

Beyond these differences, the present study identified several drivers that appear to be specific to the Nuwara Eliya context. These include serving as a pathway to organic farming, the avoidance of importing and using inferior agrochemicals, the development of social acceptance, farmer-to-farmer imitation, and competition among Chemical Leasing service provider companies. These drivers reflect the unique socio-economic, market, and production conditions faced by full-time medium-scale vegetable farmers cultivating between one and five acres in the Nuwara Eliya District and highlight the localized nature of motivations for adopting the Chemical Leasing Concept (CLC).

In addition, the interview findings revealed notable variation in agrochemical use and awareness of the Chemical Leasing concept among the surveyed farmers. A majority of respondents (77%) reported applying agrochemicals in quantities exceeding the prescribed dosage, indicating a widespread reliance on overdosing practices in vegetable cultivation. In contrast, only 23 percent of farmers adhered to recommended application limits, reflecting a comparatively lower level of compliance with regulated and sustainable agrochemical use. Regarding prior awareness of the CLC, 37 percent of participants reported that they were familiar with the concept, while the remaining 63 percent reported no prior knowledge of the Chemical Leasing concept. This substantial level of unawareness highlights an important knowledge gap, which may contribute to current agrochemical misuse and underscores the need for targeted awareness and educational interventions promoting more sustainable approaches like the Chemical Leasing concept.

Limitations of the Study

This study has several limitations that should be considered when interpreting the findings. First, the research focused exclusively on full-time, medium-scale up-country vegetable farmers cultivating between one and five acres in the Nuwara Eliya District. Consequently, small-scale, large-scale, and part-time vegetable farmers were excluded, which may limit the representativeness of the findings across the broader farming community. Although up-country vegetable cultivation is common in other central highland districts such as Badulla, Kandy, and Matale, the geographical scope of this study was restricted to the Nuwara Eliya District. Therefore, the results are context-specific and may not fully capture regional variations in farming practices, institutional support, or market conditions across Sri Lanka's up-country regions.

In addition, the study explored barriers and drivers to adopting the Chemical Leasing Concept solely from the farmers' perspective. While this approach provided valuable insights into farmers' experiences and perceptions, it did not account for the viewpoints of service providers or policymakers, whose roles are critical in the successful implementation of the CLC. Methodologically, the study employed a non-probabilistic convenience sampling technique with a sample size of 30 farmers. This limits the statistical generalizability of the findings to the wider population of up-country farmers. Furthermore, the cross-sectional research design captured perceptions at a single point in time and does not reflect potential changes in awareness, attitudes, or adoption behavior over different cultivation seasons or policy environments. Despite these limitations, the study offers meaningful exploratory insights into CLC adoption in vegetable farming in the Nuwara Eliya District and provides a foundation for future, more extensive research.

CONCLUSION

The primary objective of this study was to identify the barriers and drivers influencing the adoption of the Chemical Leasing concept among full-time medium-scale vegetable farmers in the Nuwara Eliya District. Based on the findings presented in Tables 6 and 7, the identified barriers and drivers are categorized into three groups: most significant, less significant, and other factors. The six barriers with the highest average ranking scores assigned by the 30 farmers through the Participative Ranking Method were identified as the most significant barriers to the Chemical Leasing concept adoption, while those with lower scores were categorized accordingly. Similarly, the six drivers with the highest average ranking scores were identified as the most significant drivers encouraging the Chemical Leasing concept adoption. In addition, the study identified six less significant barriers and six less significant drivers based on their relative rankings. Factors with the lowest average scores were classified as other barriers and drivers, reflecting comparatively lower influence.

However, the CLC's journey is complex yet full of potential. CLC offers an innovative vision of efficiency, sustainability, and a departure from conventional agrochemical practices. One of the considerable issues is that 77 percent of farmers excessively apply pesticides and fertilizers to their crops, while only 23 percent adhere to the prescribed standard dosage of agrochemicals among full-time medium-scale vegetable farmers in the NED. Thus, this excessive application of chemical pesticides and fertilizers is one of the fundamental issues behind health problems, the high cost of vegetable production, harvest reduction, water source contamination, the extinction of crop-friendly animals, and soil destruction. However, unawareness and unfamiliarity with the CLC are considerably high, at 63 percent. Farmers face diverse barriers unique to the Nuwara Eliya District, ranging from unawareness to payment-related problems as mentioned earlier in Table 6.

Table 6

Barriers to Adopting the Chemical Leasing Concept among Vegetable Farmers in the Nuwara Eliya District

Barriers to Adopting to the Chemical Leasing Concept among Full-time Medium-scale Vegetable Farmers in the Nuwara Eliya District		
Most Significant Barriers	1	Farmers' unawareness of the chemical leasing concept
	2	Doubt about the reality of the chemical leasing concept
	3	Uncertain weather and climate conditions
	4	The chemical leasing concept is viewed as a risk.
	5	Lack of norms, standards, and framework to implement clc
	6	The soil infertility
Less Significant Barriers	7	Lack of technical capabilities
	8	Motivations for excessive agrochemical use
	9	The education level of farmers
	10	Weaknesses of political machinery
	11	Farmers' resistance to change
	12	Beliefs on vegetable farming
Other Barriers	13	Lack of a financial risk management system
	14	Farmers' experience with excess agrochemical dosage
	15	Chemical leasing concept payment-related problems
	16	Changing seasonal crops by farmers

Source: Researchers' own work

These elements are deeply rooted in the socio-cultural and environmental context of the NED, acting as obstacles to the CLC concept. At the same time, farmers demonstrate optimism toward economic ambitions, health consciousness, and environmental stewardship. It is also clear that CLC is perceived as a solution to the problems they face in daily vegetable farming.

This study, steeped in the experiences and perceptions of local farmers, underscores the critical importance of raising awareness, facilitating access to advanced knowledge, establishing norms and standards, and fostering a sense of shared responsibility among stakeholders within the agricultural sector regarding the CLC initiative. To unlock the full potential of CLC in the NED, concerted efforts by government agencies, private entities, and educational institutions are vital. Furthermore, this research highlights the need for comprehensive awareness campaigns, knowledge-sharing platforms, financial risk

management mechanisms, and other regulatory methods to ensure the equitable distribution of benefits among farmers. Some of the problems that full-time medium-scale vegetable farmers face in vegetable farming include reliance on advice from agrochemical sellers and assistants, emergency shortages of agrochemicals and fertilizers, soil infertility, substandard agrochemicals, exploitation by intermediaries during the sale of harvest, and difficulties in selling their crops at fair prices. Along with identifying the problems faced by these farmers, the researchers conclude that the CLC represents a sustainable solution to these pressing issues based on the ideas raised by the farmers.

Table 7

Drivers for adopting the CLC among Vegetable Farmers in the Nuwara Eliya District

Drivers for Adopting the Chemical Leasing Concept among Full-time Medium-scale Vegetable Farmers in the Nuwara Eliya District		
Most Significant Drivers	1	Saving farmers' time with convenience
	2	A solution to the shortage of agrochemicals
	3	Avoiding the import and use of inferior agrochemicals
	4	Being a cost reduction and profit increase concept
	5	Being a concept that produces healthy products
	6	Can get expert knowledge
Less Significant Drivers	7	Providing environmental benefits
	8	Being a pathway to organic farming
	9	Protection against misleading advertising
	10	Awareness of the health impact of agrochemical use
	11	Favorable views of farmers (quality preservation, responsibility)
	12	Social acceptance development
Other Drivers	13	Imitating farmers
	14	Competition among chemical leasing companies

Source: Researchers' own work

Recommendations

The research findings emphasize several practical recommendations for stakeholders, such as government bodies and agrochemical importing and manufacturing companies, to promote the adoption of the Chemical Leasing concept among vegetable farmers in the country. First, a concerted effort should be directed towards increasing awareness of the Chemical Leasing concept. Unawareness of the Chemical Leasing concept is the most considerable barrier among all the barriers. Addressing the foremost barrier, namely farmers' unawareness of the Chemical Leasing concept, requires a multifaceted approach. Firstly, comprehensive awareness campaigns and educational programs should be designed and implemented to introduce the Chemical Leasing concept to farmers. These programs can be conducted through the Department of Agriculture, Sri Lanka, the National Cleaner Production Center Sri Lanka (NCPC-SL), and in collaboration with non-governmental organizations. Secondly, involving Chemical Leasing service providers in engaging directly with farmers to explain the concept, its benefits, and the practical aspects of implementation can bridge the knowledge gap. In parallel, it is recommended to underscore the potential benefits of the Chemical Leasing concept, such as cost savings, environmental sustainability, and access to quality agrochemicals. Combining these strategies can make the Chemical Leasing concept more accessible and acceptable to farmers in Sri Lanka.

Further, policymakers should consider introducing supportive policies, including incentives such as subsidies or tax benefits, to encourage more farmers to participate. In addition, it is recommended that competitions be organized to evaluate and award prizes during the initial introduction stage of the Chemical Leasing concept to encourage positive adoption by farmers. Furthermore, the government should offer technical assistance and resources while building trust among both parties, which is essential for the successful adoption of the Chemical Leasing concept. Moreover, the findings recommend a collaborative effort between private and government agricultural entities to successfully adopt Chemical Leasing among farmers across the country, particularly by developing a financial risk management scheme that is equally beneficial for both parties. Lastly, it is vital to highlight the economic and environmental benefits of the Chemical Leasing concept to farmers who prioritize cost reduction and environmental preservation. A legal framework that can secure the relationship between both parties and establish quality assurance mechanisms to verify the quality and efficiency of agrochemicals provided through Chemical Leasing companies is equally essential.

Recommendation for Future Research

This study lays the foundation for future research directions in the areas of sustainable agriculture, sustainable chemical management, and the Chemical Leasing concept. The current research employed a cross-sectional design to gather and analyze data, and future researchers can explore potential variations by utilizing longitudinal studies. There is an opportunity for future studies across different geographical regions, such as the low-country of Sri Lanka, to identify drivers and barriers to adopting the Chemical Leasing concept in relation to the use of agrochemicals in Sri Lankan vegetable farming, which may allow further generalization of the idea. In addition, future researchers may identify barriers and drivers for adopting the Chemical Leasing concept in commercial fruit cultivation, paddy cultivation, and tea cropping as well. This study examined barriers and drivers influencing Chemical Leasing adoption in vegetable farming solely from farmers' perspectives; however, future research may explore barriers and drivers of the Chemical Leasing concept from service providers' viewpoints. Further, future researchers can explore the potential use of the Chemical Leasing concept in organic farming applications. Moreover, future studies may involve a larger sample of farmers exceeding 30 participants in the Nuwara Eliya District and/or employ different research designs or methodological approaches to extend the current findings.

Additionally, there is a lack of scholarly studies on the Chemical Leasing concept in chemical-based industries that require proper chemical management, such as printing and painting, garment manufacturing, plastics and petrochemicals, cement and tile manufacturing, and cosmetics. There is an opportunity to fill these research gaps by identifying barriers and drivers for adopting the Chemical Leasing concept within the above-mentioned chemical-based industries in Sri Lanka. These recommendations aim to guide practical actions and inspire further research endeavors on the Chemical Leasing concept in the dynamic field of sustainable agriculture and other sectors in Sri Lanka. Therefore, future research can be conducted to investigate the performance of Chemical Leasing concept adoption.

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