Open Access Library Journal
2025, Volume 12, e13149
ISSN Online: 2333-9721
ISSN Print: 2333-9705

Characterization of Market Garden Production in Highlands of Minembwe Agroecological Zone in South Kivu

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How to cite this paper: Christian, M.Z., Justin, A.B., Ntale, E., Bulambo, O., Justin, M.U., Eric, R.H., Esther, A.M., Emmanuel, A.K., Aksanti, B.C., Wasso, D.S. and Lazare, R.S. (2025) Characterization of Market Garden Production in Highlands of Minembwe Agroecological Zone in South Kivu. *Open Access Library Journal*, **12**: e13149.
https://doi.org/10.4236/oalib.1113149

Received: February 24, 2025
Accepted: May 24, 2025
Published: May 27, 2025

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Abstract

Food insecurity and poverty remain critical challenges in the Democratic Republic of Congo, particularly in South Kivu, where agricultural productivity is constrained by poor infrastructure, land degradation, climatic variability, and recurrent armed conflict. In the high altitude agroecological zone of Minembwe, these constraints exacerbate food scarcity and limit income-generating opportunities. This study aimed to characterize the organic market gardening sector in this region by analyzing production systems, crop diversity, land tenure patterns, farmers' perceptions, and the use of agroecological practices, with the broader goal of strengthening food self-sufficiency and economic resilience. Using a combination of descriptive statistics and multinomial logistic regression, the study identified key socio-demographic, agronomic, and institutional factors influencing farmers' production strategies. Results show that market gardening is a vital livelihood activity, predominantly relying on family labor due to limited financial resources. Gender participation varies by locality, with men dominating in Kivumu and women more engaged in Rhunundu. Land access mechanisms differ across villages, with rental systems prevalent in Kivumu and inheritance

dominating in Rhunundu. While crop diversification is common particularly beans, cabbages, and nightshades; monocropping remains a vulnerability factor due to pest and disease risks. Organic inputs, especially animal manure (used by 71.1% of respondents), are widely adopted due to poor access to synthetic fertilizers. Farmers' perceptions indicate that the primary objective of production is twofold: ensuring household food security and generating income through local markets. However, limited market access, low purchasing power, and post-harvest losses constrain profitability. Major challenges include pest infestations (up to 97.3% in Rhunundu), climate variability, and limited access to credit and extension services. The study recommends increasing access to affordable inputs and rural credit, strengthening farmer training programs, and promoting climate-smart agriculture. Gender-sensitive land and credit policies are essential to empower women and enhance equity. Investments in integrated pest management, land tenure security, and post-harvest infrastructure are also necessary. If implemented, these interventions could significantly boost the productivity, sustainability, and resilience of market gardening systems in highlands of South Kivu.

Subject Areas

Agricultural Engineering

Keywords

Characterization, Market Gardening, Food Security, Agroecological Practices, South Kivu

1. Introduction

Food security and poverty alleviation are critical global concerns, exacerbated by factors such as low agricultural productivity, escalating costs of fertilizers and seeds, land degradation due to desertification and salinity, and the impacts of climate change. These issues have led to a scarcity of affordable food, intensifying poverty, particularly in developing nations [1].

In the Democratic Republic of the Congo (DRC), food insecurity is closely linked to limited accessibility. Inadequate storage and transportation infrastructure often result in significant post-harvest losses, thereby increasing the country's dependence on food imports [2]. The World Food Programme estimates that approximately 25.6 million individuals face crisis and emergency levels of food insecurity, with South Kivu among the most affected provinces [3].

Despite substantial food imports, malnutrition remains widespread, particularly in regions afflicted by conflict, disease, or natural disasters. Such vulnerabilities disrupt local livelihoods and perpetuate food insecurity [4]. Agriculture, a cornerstone of economic growth in developing countries, holds significant potential to reduce poverty and hunger if growth is equitably distributed [5]-[7].

In the DRC, market gardening constitutes a vital component of both urban and rural agriculture, offering opportunities to enhance food security through sustainable practices [8] [9]. In South Kivu, where family farming predominates, over 70% of the population depends on subsistence agriculture, cultivating staples such as cassava, beans, and various vegetables [10]-[12]. While market gardening and sugarcane production are expanding to meet urban demand, challenges such as climate variability, urbanization, and land tenure issues hinder progress [13]-[15].

In the highlands of Minembwe, located in South Kivu province, food insecurity remains a significant concern, with 56.5% of households experiencing moderate to severe food insecurity, compounded by high food prices and ongoing conflict [16]. Despite considerable agricultural potential, the region faces persistent challenges that hinder food production and exacerbate household vulnerability [16]. The development of vegetable farming in Minembwe is constrained by several obstacles. Access to land is a primary challenge; increasing demographic pressure in South Kivu has led to the fragmentation of agricultural lands, reducing the area available per household and complicating the expansion of vegetable farming activities [17]. Additionally, land tenure insecurity, exacerbated by local conflicts and the absence of formal property titles, discourages long-term investments in agriculture [18]. Limited access to markets and distribution channels further hampers the sale of vegetable products, diminishing economic incentives to diversify crops [16]. Recurring conflicts in the region also have a significant impact on food security, leading to population displacements, disrupting agricultural production cycles, and destroying essential infrastructure. These combined factors contribute to an increased dependence on food imports and a persistent vulnerability of households to food shortages [18].

Addressing these challenges necessitates supporting agricultural recovery through initiatives such as seed and food assistance to improve food security and resilience [19]. Vegetable crops, such as cabbage, carrots, and onions, could play a strategic role in improving local food security by enriching diets with essential nutrients and providing farmers with additional income opportunities through commercialization [20].

Introducing market garden seeds as a resilience strategy in conflict-affected areas, while integrating farmers' knowledge and practices, is critical for effective agricultural development and research [21] [22]. Reliable data on market gardening is essential to inform policies and promote biodiversity as a cornerstone of sustainable food systems [23]. Fifteen key market garden crops have been identified in South Kivu, demonstrating potential for diversification despite high agroecological constraints and conflict [8].

In light of these challenges, it is imperative to precisely characterize vegetable production in Minembwe to identify specific obstacles and propose tailored solutions focusing on production systems, crop inventories, and agroecological practices. The research seeks to contribute to food self-sufficiency for rural and

peri-urban populations in a context marked by armed conflict.

2. Methodology

This study employed a structured methodological approach comprising four key phases: an extensive literature review, a rigorous sampling strategy with clear justification, a well-designed and validated survey process, and systematic data collection and analysis.

2.1. Literature Review

A comprehensive literature review was conducted to provide a contextual foundation for the study. This phase explored the geographical, socio-economic, and biophysical characteristics of the study area, helping to refine the research objectives and guide the development of data collection tools. Sources included peer-reviewed journal articles, dissertations, project reports, books, administrative documents, and geospatial maps. The insights gained informed the selection of variables and ensured that the study framework aligned with existing knowledge on market gardening in the region.

2.2. Sampling strategy

The study involved 90 market garden producers, selected through stratified random sampling across three localities in the *Basimunyaka South grouping*: Kivumu 1, Kivumu 2, and Rhunundu. Stratified sampling was chosen to ensure proportional representation of market gardeners across different localities, thereby reducing selection bias and increasing the external validity of the findings. Given the socio-economic and environmental diversity within the study area, stratification was necessary to account for variations in land use, access to agricultural inputs, and market dynamics.

The sample size was determined using Yamane's (1967) [24], formula:

$$n = \frac{N}{1 + N\left(e^2\right)}$$

where:

n = required sample size;

N = total population of market gardeners in the study area;

e = margin of error (typically 5% or 0.05 for a 95% confidence level).

With an estimated total population of 116 market gardeners in *Basimunyaka Sud* (according to [16], the formula yielded a sample size of 90 participants. The final sample size (77.6% of the total population) was determined based on both statistical robustness and logistical feasibility. The study area has been affected by armed conflicts, leading to the displacement of populations and restricted access to certain zones. Security concerns and geographical barriers limited the ability to survey a larger group, necessitating a balance between sample representativeness and practical constraints.

Despite these limitations, the sample was distributed proportionally across the three localities: 30 participants (33.3%) in Kivumu 1, 23 participants (25.6%) in Kivumu 2 and 37 participants (41.1%) in Rhunundu.

Figure 1 shows the location of the Minembwe Highlands, situated in the Fizi and Mwenga Territory of South Kivu Province, in the eastern Democratic Republic of the Congo.

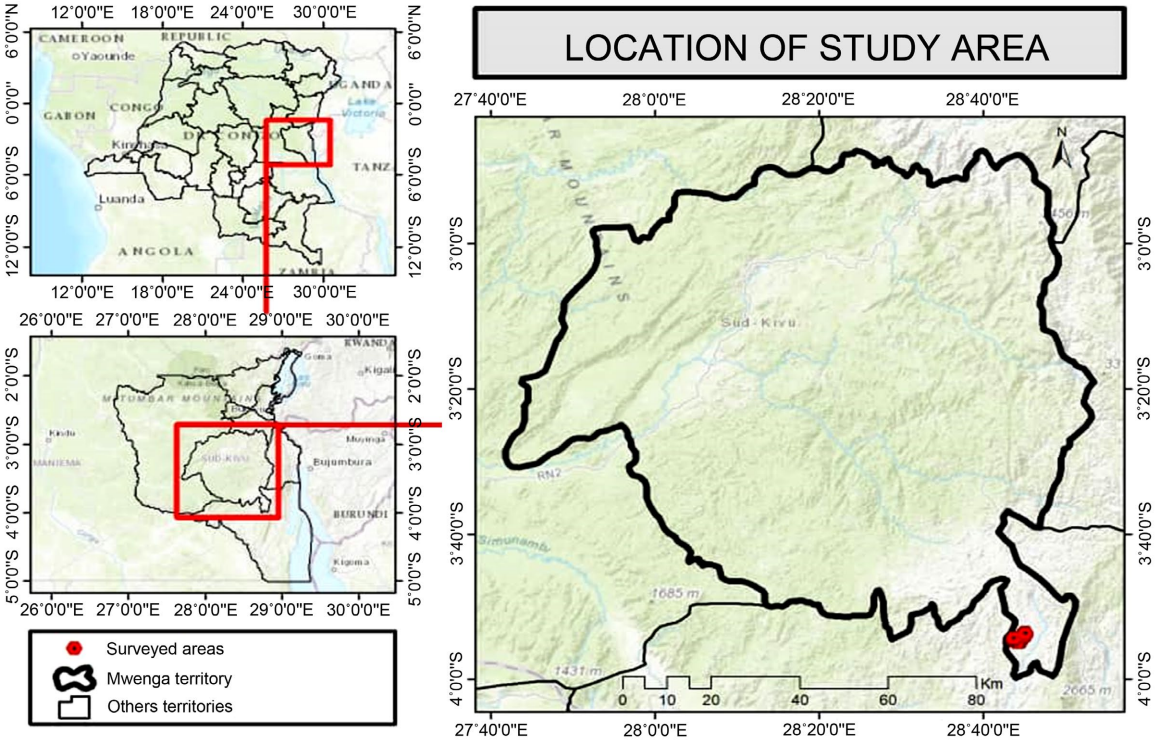

Figure 1. Location of the study area.

The survey was meticulously designed and pre-tested to ensure both its validity and reliability in capturing relevant information. The questionnaire was structured into four main sections, each addressing a critical aspect of the study. The first section focused on demographic and socio-economic characteristics, gathering details on gender, household size, and sources of income. The second section explored agricultural practices, including field size, cropping systems, sources of labor, and the use of agricultural inputs. The third section examined market dynamics, assessing farmers' access to markets, pricing mechanisms, and sales volumes. Finally, the fourth section investigated production constraints and adaptation strategies, covering challenges such as climate-related risks and pest management. Careful attention was given to the clarity and relevance of the questions. A combination of closed-ended and open-ended formats was used to facilitate both quantitative and qualitative analysis. This approach allowed respondents to provide structured answers while also offering insights into their individual experiences and perspectives.

Multiple validation steps were undertaken to enhance the validity and reliability

of the survey. First, a panel of experts in agronomy and socio-economics including co-authors reviewed the questionnaire, assessing its content validity. Their feedback led to refinements that improved question clarity and minimized potential biases. Next, a pilot survey was conducted with ten market gardeners, who were not included in the final sample. This pre-test helped evaluate the survey's understandability, internal consistency, and the average response time, ensuring that participants could engage with the questions effectively. Based on the pilot results, necessary adjustments were made before the full-scale data collection. Given the linguistic diversity of the study area, the questionnaire was also translated into Swahili, mashi and kinyamulenge to enhance accessibility. This step was particularly crucial for ensuring that respondents with limited formal education could fully understand the questions and provide accurate responses.

2.3. Field Data Collection

Data collection was conducted from June 15 to September 30, 2023, using a combination of face-to-face interviews and digital data entry via the KoBo Collect application. This approach streamlined data processing and minimized errors. The interviews were conducted on-site in each locality, allowing researchers to observe farming practices directly and clarify responses when necessary. Given the security risks in certain areas, data collection was scheduled at times and locations that ensured the safety of both respondents and enumerators.

2.4. Data Processing and Analysis

The collected data were systematically compiled into an XLS database and processed using Excel (2014) and SPSS (2020) to ensure accurate and efficient analysis. Descriptive statistics were first employed to summarize key findings, with calculations of means, frequencies, and percentages providing a clear overview of the data distribution.

To examine relationships between categorical variables, Chi-square tests (chi-2) were conducted, with a significance threshold set at $p < 0.05$, ensuring statistical rigor in detecting associations. Additionally, multicategorical regression was applied to investigate the factors influencing market gardening in the study areas further. For better visualization and interpretation of the results, findings were presented using cross-tabulations including tables.

3. Results

3.1. Characteristics of Market Garden Growers

3.1.1. Socio-Demographic Characteristics of Respondents

Table 1 summarizes the socio-demographic characteristics of respondents, including variables such as gender, age, marital status, education level, primary occupation, and market gardening training. The analysis reflects the diversity of these characteristics across the different study environments.

Table 1. Socio-demographic characteristics of respondents.

Variables	Modalities	Basimunyaka south grouping			Toal	Khi-2	P-value
		Kivumu 1	Kivumu 2	Rhunundu			
		Frequency					
Gender	Female	13.3	12.2	22.2	**47.8**	**1.32**	**0.519**
	Male	20	13.3	18.9	**52.2**		
	Total	**33.3**	**25.5**	**41.1**	**100**		
Age	15 - 30	13.3	8.9	12.2	**34.4**	**1.908**	**0.928**
	31 - 46	13.3	8.9	15.6	**37.8**		
	47 - 62	5.6	6.7	12.2	**24.5**		
	More than 62	1.1	1.1	1.1	**3.3**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Marital status	Single	1.1	4.4	4.4	**10**	**7.009**	**0.135**
	Married	30	18.9	27.8	**76.7**		
	Widower	2.2	2.2	8.9	**13.3**		
	Total	33.3	25.6	41.1	**100**		
Education Leve	Illetrate	4.4	2.2	7.8	**14.4**	**0.973**	**0.126**
	Primary	5.6	6.7	8.9	**21.1**		
	Secondary	12.2	12.2	22.2	**46.7**		
	Superior	11.2	4.4	2.2	**17.8**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Main activity	Other crops	18.8	17.8	27.8	**64.4**	**6.718**	**0.567**
	Market gardening	6.7	6.7	10	**23.4**		
	Livestock	1.1	0	1.1	**2.2**		
	Small business	1.1	0	1.1	**2.2**		
	Salaried employees	5.6	1.1	1.1	**7.8**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Past Training market gardening	Yes	15.6	14.4	27.8	**57.8**		
	No	17.8	11.1	13.3	**42.2**	**2.987**	**0.225**
	Total	**33.3**	**25.6**	**41.1**	**100**		

The findings of this study reveal a relatively balanced gender participation in vegetable farming in Minembwe, with 52.2% of producers being male and 47.8% female. The absence of a significant association between gender and location (χ^2 = 1.32; p = 0.519) highlights the inclusiveness of this activity across communities. The majority of participants fall within the economically active age group of 31 -

46 years (37.8%), followed by youth aged 15 - 30 years (34.4%), indicating increasing interest among younger generations. However, no significant variation in age distribution was observed across localities ($\chi^2 = 1.908$; p = 0.928).

A large proportion of vegetable producers are married (76.7%), potentially enhancing household labor availability and responsibility for food security. This pattern is consistent across the zones ($\chi^2 = 7.009$; p = 0.135). Education levels are relatively high, with 46.7% having completed secondary education and 17.8% having higher education, reflecting strong human capital favorable for technology adoption. The absence of significant differences by location ($\chi^2 = 0.973$; p = 0.126) suggests a uniform access to education.

In addition to horticulture, 64.4% of producers engage in other agricultural activities, mainly food crops, reflecting livelihood diversification ($\chi^2 = 6.718$; p = 0.867). Moreover, 57.8% of respondents received specific training in vegetable production, representing a key opportunity for capacity building. Training access appears evenly distributed ($\chi^2 = 2.987$; p = 0.225), underlining the potential for broad-based agricultural development interventions.

3.1.2. Farm Size, Number of the Fields and Growing Objective System

The analysis of land tenure parameters and production goals provides an insight into the agricultural exploitation strategies in this mountainous agroecological region. These factors are crucial for guiding land management policies, production support, and sustainable land use.

Table 2 shows the results relating to the number of fields, the area sown to market gardening and the objective of the system practised.

Table 2. Size of market garden farm.

Variables	Modality	Basimunyaka south grouping				Khi-2	P-value
		Kivumu 1	Kivumu 2	Rhunundu	Total		
		Frequency					
Fields detained	1	2.2	0.00	0.00	**2.2**	9.102	0.334
	2	4.4	2.2	4.4	**11.1**		
	3	5.6	3.3	13.3	22.2		
	4	8.9	7.8	12.2	**28.9**		
	More than5	12.2	12.2	11.1	**35.6**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Surface area for market garden crops	<500 m²	13.3	2.2	5.6	21.1	17.053	0.03
	1000 - 1500 m²	16.7	17.8	21.1	**55.6**		
	1500 - 2000 m²	2.2	3.3	8.9	**14.4**		
	More than 2000 m²	1.1	1.1	6.7	**8.8**		
	Total	**33.3**	**25.6**	**41.1**	**100**		

Continued

Growing objective system	No objective	1.1	0.00	0.00	**1.1**	8.653	0.193
	Product diversity	10	12.2	20	**42.2**		
	Makes garden work easier	4.4	0.00	6.7	**12.3**		
	Maximising space	17.8	13.3	14.4	**45.5**		
	Total	**33.3**	**25.6**	**41.1**	**100**		

The findings of this study reveal a relatively balanced gender participation in vegetable farming in Minembwe, with 52.2% of producers being male and 47.8% female. The absence of a significant association between gender and location (χ^2 = 1.32; p = 0.519) highlights the inclusiveness of this activity across communities. The majority of participants fall within the economically active age group of 31 - 46 years (37.8%), followed by youth aged 15 - 30 years (34.4%), indicating increasing interest among younger generations. However, no significant variation in age distribution was observed across localities (χ^2 = 1.908; p = 0.928).

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In addition to horticulture, 64.4% of producers engage in other agricultural activities, mainly food crops, reflecting livelihood diversification (χ^2 = 6.718; p = 0.867). Moreover, 57.8% of respondents received specific training in vegetable production, representing a key opportunity for capacity building. Training access appears evenly distributed (χ^2 = 2.987; p = 0.225), underlining the potential for broad-based agricultural development interventions.

3.2. Field Acquisition Method in the Study Environment

Table 3 shows how the fields were acquired in the various locations; the type of labour used by the market-gardener and the cropping systems in the various localities.

In Minembwe, vegetable farmers mainly access land through leasing (42.2%) and inheritance (36.7%), reflecting informal land tenure systems common in rural Eastern DRC. Land access methods do not vary significantly across locations (χ^2 = 9.102; p = 0.334). Family labor dominates (48.9%), with 30% working alone, indicating potential labor constraints. Paid and community labor are minimal. Labor patterns are similar across areas (χ^2 = 7.92; p = 0.244). Farming systems are balanced between monoculture (51.1%) and polyculture (48.9%) (χ^2 = 0.37; p = 0.829).

Table 3. Land acquisition mode, labour and cropping system of market garden.

Variables	Modality	Basimunyaka south grouping			Total	Khi-2	P-value
		Kivumu 1	Kivum2	Rhunundu			
		Frequency					
Land Acquisition mode	Purchase	4.4	2.2	4.4	**11.1**	9.102	0.334
	Don	5.6	2.2	2.2	**10**		
	Heritage	8.9	10	17.8	**36.7**		
	Rental	14.4	11.1	16.7	**42.2**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Work force used	Support	1.1	4.4	4.4	10	7.92	0.244
	Family	18.9	13.3	16.7	**48.9**		
	Individual	7.8	7.8	14.4	**30**		
	Salary	5.6	0	5.6	**11.1**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Crop system	Monoculture	16.7	14.4	20	**51.1**	0.37	0.829
	Polyculture	16.7	11.1	20	**48.9**		
	Total	**33.3**	**25.6**	**41.1**	**100**		

3.3. Cultural Methods and Input Management

Table 4 shows the results for sowing method, seed source, crop mulching and water source.

Table 4. Cultivation techniques used by market gardeners.

Variables	Modality	Basimunyaka south grouping			Total	Khi-2	P-value
		Kivumu 1	Kivumu 2	Rhunundu			
		Frequency					
Sowing method	On fly	6.7	5.6	4.4	16.7	1.58	0.454
	On line	26.7	20	36.6	83.3		
	Total	33.4	25.6	41	100		
Origin of the seed	The local market	7.8	5.6	8.9	22.2	3.79	0.435
	Other farmers	2.2	0	5.6	7.8		
	Previous harvest	23.3	20	26.7	70		
	Total	33.3	25.6	41.1	100		
Mulching crops	Yes	7.8	3.3	4.4	15.5	2.126	0.345
	No	25.6	22.2	36.7	84.5		
	Total	33.4	25.5	41.1	100		

Continued

Source of water in the garden	Rain	2.2	0	16.7	18.9	28.9	**0.00**
	Rivers	4.4	0	0	4.4		
	Rivers and rain	25.6	25.6	24.4	75.6		
	Source	1.1	0	0	1.1		
	Total	**33.3**	**25.6**	**41.1**	**100**		

Line seeding is predominantly practiced by 83.3% of farmers in Minembwe, with no significant variation across localities (χ^2 = 1.58; p = 0.454), due to its agronomic benefits like planting density control and ease of maintenance. Most farmers (70%) use seeds from previous harvests, reflecting self-sufficiency but raising concerns about genetic diversity and seed quality. Market supply (22.2%) and seed exchange (7.8%) remain low, with no location-based differences (χ^2 = 3.79; p = 0.435). Mulching is rarely practiced (15.5%), likely due to lack of training or biomass (χ^2 = 2.126; p = 0.345). Irrigation is mainly from mixed rainwater and rivers (75.6%), but access is unequal (χ^2 = 28.9; p = 0.000), calling for investment in water infrastructure.

3.4. Fertilisation of Market Garden Fields and Use of Pesticides in Market Garden Crops

The analysis of fertilization and plant protection practices in Minembwe reveals some adaptation by producers to local agroecological constraints.

3.4.1. Fertilisation of Market Garden Fields

Table 5 shows the results for fertiliser use, types of fertiliser and fertility assessment.

Table 5. Fertilizer application practices and soil fertility perception among farmers.

Variables	Modalities	Basimunyaka South grouping			Total	Khi-2	P-value
		Kivumu 1	Kivumu 2	Rhunundu			
		Frenquency					
Use of fertilisers	Yes	25.6	24.4	32.2	**82.2**	3.845	0.145
	No	7.8	1.1	8.9	**17.8**		
	Total	**33.4**	**25.5**	**41.1**	**100**		
Types of fertilisers	No one	7.8	1.1	8.9	**17.8**	11.57	0.171
	Compost	0	2.2	5.6	**7.8**		
	Plant debris	0	1.1	0	1.1		
	Chemical fertilisers	1.1	0	1.1	**2.2**		
	Animal manure	24.4	21.1	25.6	**71.1**		
	Total	**33.3**	**25.6**	**41.1**	**100**		

Continued

Assesment of soil fertility	Low	17.8	11.1	15.6	**44.4**	2.57	0.634
	Average	7.8	6.7	8.9	**23.3**		
	High	7.8	7.8	16.7	**32.2**		
	Total	**33.4**	**25.6**	**41.1**	**100**		

In Minembwe, 71.1% of vegetable farmers use animal manure, reflecting adaptation to local constraints and a move toward sustainable practices (See Table 5). However, this is often insufficient in areas where 44.4% report low soil fertility. The use of chemical fertilizers remains very low (2.2%), likely due to cost, limited access, and lack of technical knowledge. No significant differences were found between localities ($p > 0.05$), indicating homogeneity in fertilization practices. This uniformity offers opportunities for coordinated, sustainable soil fertility improvement strategies.

3.4.2. Use of Plant Protection Products

Table 6 describes the results of pesticide use and the types of pesticides applied.

Table 6. Use of plant protection products in market gardening.

Variables	Modalities	Basimunyaka south grouping			Total	Khi-2	P-value
		Kivumu 1	Kivumu 2	Rhunundu			
		Frequency					
Use pesticides	Yes	18.9	17.8	26.7	**63.4**	0.996	0.608
	No	14.4	7.8	14.4	**36.6**		
	Total	**33.4**	**25.5**	**41.1**	**100**		
Pesticides types	Unknown	7.8	1.1	8.9	**17.8**	15.602	0.016
	Plant extract	13.3	17.8		**33.3**		
	Chemicals fungicids	3.3	4.4	0	**7.8**		
	Chemicals insecticids	8.9	2.2	14.4	25.6		
	Total	**33.3**	**25.6**	**41.1**	**100**		

Regarding plant protection, the study shows that 63.4% of farmers use pesticides, with 33.3% favoring plant-based biopesticides—an agroecologically positive trend. However, 17.8% of producers are unaware of the exact type of pesticide used, reflecting gaps in training and potentially affecting efficacy and safety. The significant variation in pesticide types across localities ($\chi^2 = 15.602$; $p = 0.016$) suggests disparities in input access or influence from local traditions and extension services, underlining the need for improved farmer education and more equitable plant protection input distribution.

3.5. Estimating Production and Its Destination

Table 7 shows the results of estimating production and the destination of production.

Table 7. Estimated market garden production and use in Minembwe.

Variables	Modalities	Basimunyaka South grouping			Total	Khi-2	P-value
		Kivumu 1	Kivumu 2	Rhunundu			
		Frequency					
Estimating production	Low	3.3	4.4	26.7	**12.2**	1.178	0.882
	Average	17.8	11.1	18.9	**47.8**		
	High	12.2	10.1	17.8	**40**		
	Total	**33.3**	**25.6**	**41.1**	**100**		
Destination of the production	Self cousumption	16.7	8.9	20	**45.6**	3.221	0.522
	Aid	3.3	2.2	6.7	**12.2**		
	Sale	13.3	14.4	14.4	**42.1**		
	Total	**33.3**	**25.6**	**41.1**	**100**		

Nearly 88% of producers in Minembwe perceive their vegetable yields as average or high, reflecting a positive trend despite input and fertility challenges. The absence of significant locality-based differences ($p = 0.882$) suggests shared conditions in land access, knowledge, and climate. Market gardening serves both self-consumption (45.6%) and commercial purposes (42.1%), indicating a semi-commercial subsistence model. Donations remain limited (12.2%), emphasizing production's focus on household food security and income generation.

3.6. Different Crops Produced in the Area

The plant diversity observed reflects adaptation to high-altitude agroecological conditions and local diets. Cabbage (Brassica oleracea) dominates, underlining its nutritional and cultural value. Solanaceae crops like tomatoes and eggplants are also significant, despite their irregular distribution and disease susceptibility, suggesting influences from technical or logistical factors. Crops like carrots, peppers, and peas remain rare (<25%), likely due to poor adaptation, limited demand, or specific agronomic constraints. (See Table 8)

Table 8. The different crops grown in the localities surveyed.

Basimunyaka south grouping				Rhunundu	Kivumu 1	Kivumu 2
Name	**Family**	**Scientific name**	**Cousumed organs**	**Frequency**		
Cabbage	Brassicaceae	*Brassica oleracea* L.	Apple	97.3	90	100
Bean	Fabaceae	*Phaseolus vulgaris*	Leaves and et fruits-legumes	89.2	93.3	100

Continued

Nightshade	Solanaceae	*Solanum scabrum*	leaves	89.2	86.7	82.6
Eggplant	Solanaceae	*Solanum melongena* L.	Fruits	86.5	73.3	65.2
Amaranths	Amaranthaceae	*Amaranthus spp*	Leaves	75.9	76.7	73.9
Onion	Amaryllidaceae	*Allium cepa L.*	Bulb-leaves	73	73.3	56.5
Squash	Cucurbitaceae	*Cucurbita pepo*	Fruits	59.5	60.5	52.2
Tomato	Solanaceae	*Solanum lycopersicum L.*	Fruits	32.4	23.3	26.7
Carrots	Apiaceae	*Daucus carota subsp. Sativus*	Roots	8.1	13.3	21.7
Peanuts	Fabaceae	*Arachis hypogea*	Legumes	13.5	3.4	3.3
Chillies	Amaryllidaceae	*Capsicum frutescens L.*	Fruits	0.00	3.3	0.00
Pea	Fabaceae		Legumes	2.7	4.3	2.7

3.7. Different Possible Associations in the Study Environments

Table 9 describes the cropping associations practiced in the environments studied.

Table 9. Crop combinations and botanical family associations in the surveyed agroecosystems.

Basimunyaka localities		Rhunundu	Kivumu 1	Kivumu 2
Crop associations	**Family associations**	**Frequency**		
Amaranth-Maize	Amaranthaceae -Poaceae	87.8	63.3	100
Amaranth-eggplant	Amaranthaceae-Solanaceae	35.1	13.3	34.8
Bean-eggplant	Fabaceae-Solanaceae	21.6	26.7	0.00
Eggplant-Maize	Solanaceae-Poaceae	8.1	10	0.00
Tomato-eggplant	Solanaceae-Solanaceae	13.5	0.00	0.00
Tomato-maize	Solanaceae-Poaceae	5.4	0.00	0.00
Onion-carrots	Amaryllidaceae-Apiaceae	2.7	0.00	0.00

Local market gardening systems in Minembwe rationally adopt crop associations to enhance productivity and resilience. The Amaranth-Maize pairing (87.8%; 63.3%; 100%) is most prevalent due to its agronomic synergy: amaranth offers rapid soil coverage, while maize grows vertically, minimizing competition. More complex combinations like Amaranth-Eggplant (35.1%; 13.3%; 34.8%) or Bean-Eggplant (21.6%; 26.7%) require careful planning to manage resource competition. Solanaceae pairings (e.g. Tomato-Eggplant) are rare due to shared disease risks demanding stricter phytosanitary control. (See Table 9)

3.8. Analysis of Socio-Demographic and Technical Determinants of Participation in Vegetable Production

An assessment of the socio-demographic, agronomic, and technical factors

influencing farmers' participation in vegetable production was conducted using a multinomial logistic regression model.

Table 10. Socio-deographic and technical and production practice factors.

Socio-demographics factors	Estimate Std.	P value	OR	IC (95 %)
(Intercept)	−13.69853	0.993	1.124096e−06	[0.00, 1.00]
Localities: Kivumu 2	0.01785	0.980	1.018010e+00	[0.00, 1.00]
Localities: Rhunundu	−0.09218	0.890	9.119423e−01	[0.00, 1.00]
Sex: Male	−0.06458	0.920	9.374638e−01	[0.00, 1.00]
Marital status: maried	−1.14501	0.234	3.182215e−01	[0.00, 1.00]
Marital status: not maried	−1.30790	0.341	2.703880e−01	[0.00, 1.00]
Level of study: primary	−0.97291	0.293	3.779800e−01	[0.00, 1.00]
Level of study: secondary	−0.47847	0.599	6.197326e−01	[0.00, 1.00]
Level of study: university	−1.32012	0.282	2.671027e−01	[0.00, 1.00]
Seniority in market garden	0.07004	0.136	1.072551e+00	[0.00, 1.00]
Training in market gardening: yes	−0.77091	0.197	4.625931e−01	[0.00, 1.00]
Number of fields: 2	13.62543	0.994	8.268926e+05	[0.03, 0.52]
Number of fields: 3	13.81762	0.993	1.002108e+06	[0.06, 0.43]
Number of fields: 4	13.74503	0.993	9.319454e+05	[0.07, 0.37]
Number of fields: > 5	14.49943	0.993	1.981626e+06	[0.16, 0.50]
Specific factors to the market gardening production system	**Estimate Std.**	**P-value**	**OR**	**IC (95 %)**
(Intercept)	−33.22119	0.9976	3.734409e−15	[0.00, 1.00]
Work force: Family	15.13387	0.9989	3.737303e+06	[0.00, 1.00]
Work force: Individual	15.17833	0.9989	3.907185e+06	[0.00, 1.00]
Work force: salaried	−4.06843	0.9997	1.710418e−02	[0.00, 1.00]
Acquisition: Donation	37.14096	0.9960	1.349322e+16	[0.00, 1.00]
Acquisition: Inheritance	−1.35473	0.4063	2.580163e−01	[0.00, 1.00]
Acquisition: Lease	−2.88555	0.0846.	5.582406e−02	[0.00, 1.00]
Surface area: < 500 m^2	1.07996	0.3506	2.944570e+00	[0.00, 1.00]
Surface area: 1500 to 2000 m^2	2.44046	0.0244*	1.147832e+01	[0.00, 1.00]
Surface area: 2000 m^2 and over	−0.13457	0.9149	8.740950e−01	[0.00, 1.00]
Surface area: unknown	−14.52381	0.9989	4.924820e−07	[0.00, 1.00]
Farming system: polyculture	−19.21423	0.9978	4.522378e−09	[0.00, 1.00]
Farming system: Monoculture	−0.76915	0.4399	4.634083e−01	[0.00, 1.00]
Farming system: Rotation	−15.19963	0.9989	2.505435e−07	[0.00, 1.00]

Continued

Origin of seed: other market gardeners	0.11643	0.9467	1.123474e+00	[0.00, 1.00]
Origin of seed: last harvest	0.65452	0.5739	1.924218e+00	[0.00, 1.00]
Sowing: on fly	−0.50008	0.6324	6.064820e−01	[0.00, 1.00]
Fertilization: yes	17.15538	0.9940	2.821533e+07	[0.00, 1.00]
Phytosanitary products: yes	0.68888	0.4152	1.991484e+00	[0.00, 1.00]
Estimated Production: High	0.82459	0.6773	2.280941e+00	[0.00, 1.00]
Estimated Production: average	−0.04887	0.9787	9.523064e−01	[0.00, 1.00]
Destination of production: mutual aid	2.38761	0.1049	1.088747e+01	[0.00, 1.00]
Destination of production: for sale	0.96705	0.3769	2.630164e+00	[0.00, 1.00]

An assessment of the socio-demographic, agronomic, and technical factors influencing farmers' participation in vegetable production reveled that geographically, location does not significantly impact participation ($p = 0.980$ and $p = 0.890$). Gender, marital status, and education level also show weak or non-significant associations with vegetable farming, although more educated individuals may be less inclined to engage. Years of agricultural experience have a slight positive effect (OR = 1.07). Land access and farming practices like family or individual labor (OR > 3.7 million) are critical, while donation-based land acquisition strongly supports vegetable farming (OR $\approx 1.3 \times 10^{16}$). Cultivated area between 1500 - 2000 m^2 significantly increases participation (OR = 11.47). The use of fertilizers (OR $\approx 2.82 \times 10^{7}$) and the social role of production (OR = 10.89) also emerge as important factors, although input usage varies in significance. (See Table 10)

3.9. Perceived Constraints and Opportunities in Market Gardening in the Basimunyaka South Agroecological Zone

The distribution of agroclimatic, technical, and socio-political constraints, as well as the opportunities related to market gardening activities across the studied areas, is presented in Table 11.

The analysis of constraints faced by vegetable farmers reveals key challenges in Minembwe. Pests and diseases are the most common issue, reported by up to 97.3% of respondents, reflecting significant phytosanitary pressure. Climatic disturbances, such as irregular rainfall, affect 82.6%-85% of producers, disrupting agricultural schedules. Water-related issues vary, with flooding in some areas and scarcity in others, highlighting spatial disparities. Post-harvest conservation problems affect 36.5% - 56.8% of farmers, reducing marketability. The lack of agricultural extension services (up to 98.2%) and limited access to credit (60%-82.6%) hinder progress. Insecurity, affecting 53.3%-89.2% of farmers, further impacts farming dynamics. Despite these constraints, vegetable farming offers opportunities such as job creation (91%), income generation (60% - 91.3%), and

food self-sufficiency (81.1% - 100%), though environmental awareness remains limited.

Table 11. Constraints and opportunities linked to the production of market garden crops.

Basimunyaka localities		Rhunundu	Kivumu 1	Kivumu 2
Constraints linked tothe production of market garden crops				
Constraints	**Modalities**		**Frequency**	
Agroclimatics	Attack by crop pests and deseases	97.3	60	91.3
	Lack of water	23.3	43.5	29.7
	Difficulty for preserving product	36.5		56.8
	Excess of water	51.4	43.3	43.3
	Climate disturbance	83.3	85	82.6
Technicals	Lack of technical support	98.2	26.7	87.7
	Lack of agricultural credit	78.4	60	82.6
	Products flows problems	32.4	17.4	0.00
Socio-politics	Security conflicts	89.2	53.3	87
Market gardening opportunities				
Opportunities			**Frequency**	
	Source of income	81.1	60	91.3
	Job creation	91.8	91.3	95.7
	Food self-consumption	100	81.1	100
	Waste recycling	0.00	3.3	0.00

4. Discussion

The results from this study on market gardening in Minembwe reveal several trends that resonate with findings from other regions, while also highlighting unique local dynamics.

A higher male participation rate in market gardening (52.2%) compared to females (47.8%) was observed, with male dominance more evident in Kivumu 1 and Kivumu 2, while Rhunundu reported a greater involvement of women. This gender distribution mirrors findings from rural areas in Sub-Saharan Africa, where men often dominate due to their greater access to land, capital, and extension services [25] [26]. However, the strong female representation in Rhunundu aligns with studies such as [26], which emphasize the critical role women play in food production and household nutrition. These variations highlight the importance of gender-sensitive policies that promote equitable access to productive resources for both men and women.

The reliance on family labor 24.4% in Kivumu 1 and 35.6% in Rhunundu aligns

with trends seen in similar agroecological zones. In such contexts, family labor remains the main source of workforce, especially where access to hired labor is constrained by financial limitations [27]-[29]. This pattern suggests that market gardening in Minembwe is deeply embedded within household livelihood strategies that balance subsistence needs with income generation.

Land acquisition practices varied by locality: renting predominates in Kivumu 1 and Kivumu 2, while inheritance is more common in Rhunundu. These findings are consistent with [30]-[32], who emphasized the growing role of informal rental markets in Ethiopia as a means for land-constrained farmers to expand production, albeit at significant cost. Meanwhile, the reliance on inheritance systems mirrors [33] [34]'s findings in Uganda, which highlight the challenges posed by land fragmentation and tenure insecurity under traditional systems. These dynamics underscore the need for policies that support secure and equitable land tenure, particularly for women and youth.

The study revealed a moderate level of crop diversification, with a focus on beans, cabbages, and nightshades. This diversification strategy is consistent with findings from the Sahel and East Africa, where it serves as a risk-mitigation tool against climatic shocks, pests, and market volatility [35]. However, the persistence of monocropping (especially in beans and cabbages) in parts of Minembwe could heighten vulnerability to pest and disease outbreaks, a concern raised by [36], [37] in similar contexts in Nigeria.

The use of organic fertilizers especially cow and goat manure by 71.1% of respondents is widespread and reflects a common trend in resource-constrained regions where access to commercial fertilizers is limited. This mirrors findings in Kenya, where the high cost and limited availability of synthetic inputs led smallholder farmers to rely on organic alternatives [38]-[40]. However, the limited use of compost and chemical fertilizers (only 2.2%) may point to gaps in knowledge or accessibility, a challenge echoed in [41], [42]'s study in Zambia.

Pest pressure was reported by 60% of respondents in Kivumu 1, 91.3% in Kivumu 2, and 97.3% in Rhunundu, confirming that insect pests are a major constraint to vegetable production in the region similar to findings by [43] in Rwanda, Burundi and [37] in the DRC. Farmers' responses to this challenge included the use of pesticides (63.3%), with a notable proportion (33.3%) relying on plant-based extracts. This mirrors integrated pest management strategies employed in other parts of Africa, where chemical and organic controls are used in tandem due to economic or environmental concerns [44].

Climatic disturbances, including irregular rainfall, were also identified as a major constraint, reflecting broader regional trends. Unpredictable weather patterns such as droughts and floods are increasingly affecting smallholder farmers across East Africa, leading to crop failures and food insecurity [45]. These climatic challenges call for the adoption of climate-smart agricultural practices, such as water harvesting and stress-resilient crop varieties.

Limited access to credit and agricultural extension services emerged as major constraints. In Kivumu 2, for instance, the low availability of technical support

mirrored findings from [46], who noted that the lack of training and advisory services inhibits the adoption of improved practices. Likewise, the restricted access to credit reported by 60% to 82.6% of respondents is consistent with studies in Kenya and Rwanda, where informal financial systems dominate but fail to meet the capital needs of farmers [47] [48]. Strengthening extension systems and rural financial services is thus essential to improving productivity and resilience.

Despite numerous constraints, market gardening contributes significantly to food security and livelihoods in Minembwe. A large proportion of produce is destined for household consumption (90% in Kivumu 1, 100% in Kivumu 2), illustrating the sector's subsistence value. This dual role feeding the household while generating income is corroborated by findings in rural zones of West and East Africa [49]-[52]. Moreover, market gardening is seen as a source of employment and income, as highlighted by over 91% of respondents, consistent with [53], who showed that vegetable production significantly contributes to rural livelihoods through job creation and income diversification.

However, the limited emphasis on sustainability practices such as composting and waste recycling (reported by only 3.3%) indicates untapped potential for integrating agroecological principles. In contrast, farmers in Kenya and South Africa are increasingly adopting circular approaches, including compost use and organic waste recycling, to address environmental degradation and enhance soil fertility [54]-[56].

The multinominal logistic regression model findings reveal that land tenure, labor organization, and socio-economic motivations are key determinants of engagement in vegetable production. The strong positive correlation between ownership of multiple plots and active participation supports policies aimed at land security and equitable land distribution [57] [58]. Meanwhile, the preference for family labor over salaried work underscores the need for labor productivity-enhancing measures, including small-scale mechanization and cooperative labor schemes [59]. Interestingly, the positive association between donation-based distribution and participation in production (OR = 10.89) suggests the embeddedness of agriculture within local solidarity systems. This finding calls for policies that recognize both the market and social functions of agriculture, especially in fragile or post-conflict areas.

5. Conclusion

This study emphasizes that while market gardening in highlands of Minembwe holds great promise, its potential will only be fully realized through targeted and inclusive interventions. Strengthening technical support, ensuring gender equity, improving access to inputs and financial services, and enhancing climate resilience are all essential to fostering a more sustainable and productive agricultural sector in the region. With appropriate support and investment, market gardening can serve as a pillar of rural development and a pathway to improved livelihoods for farming households in Minembwe.

Acknowledgements

The authors would like to thank the market gardeners for their time during the data collection phase.

Conflicts of Interest

The authors declare no conflict of interest.

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