fortune Journals

Research Article

JOURNAL OF FOOD SCIENCE AND NUTRITION RESEARCH

ISSN: 2642-1100

Effect of Kitchen Garden Training on Food Security in Goma City, Democratic Republic of Congo

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Abstract

Background: Chronic conflict, displacement, and urbanisation have resulted in households in informal settlements in Goma City, Democratic Republic of Congo (DRC) being among the most food-insecure urban populations in sub-Saharan Africa, but with limited evidence on nutrition-sensitive interventions.

Objective: To assess the effect of kitchen gardening training on household food security in Goma City.

Methods: A quasi-experimental, controlled before-after design compared 181 intervention and 181 control households using the Household Food Insecurity Access Scale (HFIAS), Food Consumption Score (FCS), and Household Dietary Diversity Score (HDDS) at baseline and endline, complemented by focus group discussions.

Results: At baseline, 92.3% of intervention and 90.1% of the control were severely food insecure; there was no difference between the groups at baseline. After training, the HFIAS score improved by a net of 8.29 points compared to the control arm (Cohen's $d=3.74$, $p<0.001$); severe food insecurity decreased by 92.3% to 0% in the intervention group and increased by 99.4% in the control group (difference-in-differences = -101.6%, $p<0.001$). There was also a net improvement of 13.26 points in FCS and 2.26 points in HDDS. The improvement was associated with households reporting a higher crop diversity, cultivation periods, harvesting frequency, and irrigation. Households that harvested more than 10 kg per cycle increased by a net of 27.7% due to good management of the gardens and not arable land expansion. Moreover, the highest gains were reported among female-headed households. However, female-headed households were more food insecure than their male-headed counterparts at endline due to limited access to water, land, and time.

Conclusion: Community-based kitchen gardening training is a key intervention that can bridge the gap between severe and moderate food insecurity levels for urban households in humanitarian settings. However, there is a need for continued investment in water, tenure, and women's empowerment to ensure sustainability.

Keywords: Food security; Kitchen gardening; Household Food Insecurity Access Scale; Food Consumption Score; Urban agriculture; Gender; Difference-in-differences; Democratic Republic of Congo

Introduction

Food security is a condition where all people, at all times, have physical,

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Citation: Mafuko Nzamurata, Leo Ogallo, Agrippina Lubeka. Effect of Kitchen Garden Training on Food Security in Goma City, Democratic Republic of Congo. Journal of Food Science and Nutrition Research 9 (2026): 124-138

Received: August 06, 2026
Accepted: July 08, 2026
Published: September 16, 2026

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs for an active and healthy life, encompassing the availability, access, utilisation, and stability components [1,2]. Sustainable Development Goal (SDG) 2 promotes the global agenda of eradicating hunger and ensuring food security by 2030 [3]. However, the attainment of this target has proven challenging, with fragile and conflict-affected countries facing the highest levels of food insecurity [4].

The East of the Democratic Republic of Congo (DRC) has been subjected to decades of conflict and displacement, fuelling rapid and unplanned urbanisation in Goma City, North Kivu, characterised by informal settlement formation with limited access to agricultural land, poor infrastructural development, and inadequate market access [5]. As a result, most households in the informal settlements are currently classified as severely food insecure in Goma City [4]. This is partly because the informal settlements face a higher-than-average risk of experiencing multiple income and food price shocks, with limited access to substitutes [4]. In such a context, promoting food security entails considering the availability of food (production and stocks), economic and physical access to food (lower costs and market access), and stability with respect to income and price fluctuations to cushion households from future shocks [5].

The small-scale production of vegetables, tubers, and legumes in domestic and community gardens, better known as kitchen gardening, has been advanced as a nutrition-sensitive food-security intervention due to its potential to act on more than one pillar of food security simultaneously: by boosting local food production, it can both increase the availability of home-grown crops and reduce spending on vegetables, with knock-on benefits for other areas of the household budget, while its capacity to build resilience in the face of covariate shocks in the food system is considerable [6,7]. Experience from around the world demonstrates that kitchen and home gardening can enhance household food security and dietary quality: in Rwanda [8], Bangladesh [9], Myanmar [10], South Africa [11], and Brazil [12]. Moreover, innovative methods such as sack and vertical gardening have been shown to generate significant gains in both food security and dietary diversity in the most confined spaces, including informal urban settlements such as Kibera, Nairobi [13,14].

Meanwhile, a number of studies have examined why, in some cases, urban agriculture and kitchen gardens fail to deliver on their considerable promise, identifying a range of social, economic, and environmental factors that undermine the capacity of urban farmers to adopt new practices and technologies and therefore diminish their impact on household food security. Water scarcity, tenure insecurity, limited access to agricultural inputs, gender norms, a lack of extension services, and market-access challenges all contribute to a general shortfall in 'provisioning capacity' observed across a range of contexts [15-18]. Additionally, a few studies found that the physical limitations of the built environment in densely populated urban areas could hinder the ability of even intensive interventions to improve dietary diversity and food security in the long term [19,20]. Finally, the role of gender in kitchen gardening is multifaceted: women are often disproportionately involved in the cultivation of home gardens but simultaneously constrained in their ability to adopt innovations due to their generally lower income, lesser access to land, and limited spare time compared to their male counterparts. As a result, female-headed households are likely to be both particularly vulnerable to food insecurity and to have fewer resources with which to address it through kitchen gardening interventions [21-23].

Despite the growing body of evidence, there is a need for quasi-experimental studies that examine the effectiveness of kitchen gardening training on household food security, as measured by established composite indicators such as the Household Food Insecurity Access Scale (HFIAS) and the Food Consumption Score (FCS), together with its underlying mechanisms of production, in conflict-affected Central African cities. No prior study has used a difference-in-differences design to assess the intervention's effect on food-insecurity severity and food-consumption adequacy, or to evaluate its impact on household garden productivity, in Goma City. Additionally, the extent to which the intervention may differentially affect male- and female-headed households, and the ways in which contextual barriers to production may constrain these effects, are not well understood.

This study fills this research gap by assessing the effect of a participatory kitchen gardening training programme on household food security among informal settlers in Goma City, DRC. Specifically, the study (i) determines the baseline characteristics of household food security, food consumption, and production levels in the intervention and control groups before training, with an added exploratory gender analysis; (ii) estimates the difference-in-differences effect of the training programme on the HFIAS score and food-insecurity category, FCS, HDDS, and production levels, while controlling for gender; and (iii) identifies the factors that hindered kitchen garden establishment and sustainability practices among study participants, even among those who received training, as a basis for recommending effective strategies for scaling up food-security interventions in urban Goma and similar fragile contexts.

Materials and Methods

Study design and setting

A quasi-experimental, controlled, pre-post (baseline-endline) design was used to assess the effect of kitchen gardening training on the household food security of informal-

Citation: Mafuko Nzamurata, Leo Ogallo, Agrippina Lubeka. Effect of Kitchen Garden Training on Household and Individual Dietary Diversity in Goma City, Democratic Republic of Congo. Journal of Food Science and Nutrition Research. 9 (2026): 124-138.

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

settlement dwellers in Goma City, North Kivu Province, DRC. Informal, unplanned settlements are located on volcanic terrain and are characterised by agriculture organised around three seasons: Season A (September-February), Season B (February/March-June/July), and Season C (July-September) [2,24]. Short-cycle crops with a harvesting period of no more than three months dominate local production because of the specific characteristics of the terrain and land-plot sizes in informal settlements. Examples include amaranth, spinach, tubers, bush beans, eggplant, carrots, early tomato varieties, and onions. Baseline data collection was conducted in February 2026, marking the beginning of Season B and the start of the rains, while endline data were collected in early June 2026, representing the period of crop maturity and harvest. The intervention was implemented within a single season to avoid comparing different crop cycles.

Control and intervention groups were selected from similar informal-settlement areas to account for differences in the level of services and infrastructure (or the lack thereof). A difference-in-differences (DiD) approach was applied to estimate the intervention's impact on the food security of informal dwellers. This choice is justified by potential confounding factors influencing trends in the control and treatment groups, including seasonal fluctuations in food prices, rainfall patterns, and macroeconomic shocks affecting the whole of Goma [4].

Sample size and sampling

Out of the 362 households that were selected, 181 were intervention households, and 181 were control households. The 362 households were selected from informal settlements in Goma City by first identifying possible neighbourhoods using the purposive sampling method and then applying the systematic random sampling technique to pick the representative households from the selected neighbourhoods. All the 362 households selected were involved in the baseline and endline surveys to mark a 100% response rate. This was achieved through the support of community leadership and health volunteers who facilitated the household identification and recruitment process.

The kitchen gardening training intervention

The intervention involved training on short-cycle crops and legumes production, diversification of crops in the kitchen-garden to enhance food and nutritional security, improved composting and water conservation such as rainwater harvesting and hand watering or irrigation of the kitchen-garden. The intervention further comprised training on disease and pests control, harvesting, and basic home nutrition to improve food and nutritional security. The comparison group received no intervention during the study period and was told that they would be provided with the intervention package after the endline survey, as it was a delayed intervention design. The intervention was implemented using group discussions, demonstrations and home visits as participatory tools. This approach had been found effective in promoting the adoption of kitchen gardening by the poor and vulnerable community [25].

Data collection instruments

Collection of Data was done Using Questionnaires and Focus Group Discussion. Data collection was done at baseline and endline using structured interviewer administered household questionnaires and focus group discussions (FGDs). The questionnaires obtained information on socio-demographic and economic characteristics of households and kitchen-garden production and household food security. Household food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS), Food Consumption Score (FCS) and Household Dietary Diversity Score (HDDS). Information collected on kitchen-gardens included the size, type, crop diversity, duration of production, water source, harvesting frequency and quantity harvested. Both baseline and endline FGDs were conducted with the study participants. The issues addressed during the discussion included factors affecting establishment and maintenance of kitchen gardens. This was done using a checklist of key technical, environmental, socio-cultural and market factors hindering food production activities. The qualitative data collected were analysed thematically while the quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS).

Data analysis

Descriptive statistics (frequency tables, means, and standard deviations), Pearson's chi-square tests and odds ratios (with 95% confidence intervals) for categorical data, independent sample and paired sample t-tests, one-way analysis of variance for continuous variables, multinomial logistic regression/generalised estimating equations for categorical DID outcomes, and difference-in-differences analyses were used to analyse the data. For the main DID analysis, the focus was on the net treatment effect, which was estimated as the difference between the treatment group's mean outcome change from baseline to endline and the mean change in the control group over the same period. Wherever possible, effect sizes were reported using Cohen's d to indicate the size of the observed changes. The threshold for statistical significance was set at $p<0.05$, with a 95% confidence interval. Thematic analysis of qualitative data was performed to complement and inform the quantitative findings.

Ethical considerations

The study was conducted according to ethical principles and guidelines for human research. The study was approved by Great Lakes University of Kisumu Scientific and Ethical

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

Review Committee (GLUSERC) and the relevant DRC authorities. Informed consent was obtained from respondents' households via consent forms. Households that gave their informed consent were assured of the confidentiality of the information provided. Control households were told that they would receive the intervention package after the endline survey, which is a standard procedure in a delayed-intervention controlled design.

Results

Socio-demographic and economic characteristics of study households

Table 1 below presents the socio-demographic and economic characteristics of the head of the household in the intervention and control arms of the study (N=362). The two arms were found to be comparable across all the measured

Table 1: Socio-demographic and economic characteristics of household heads in the intervention and control groups (N = 362)

Variable	Category	Intervention (n=181) n (%)	Control (n=181) n (%)	df	χ2	p-value
Sex of household head	Male	100 (55.2)	97 (53.6)	1	0.08	0.777
	Female	81 (44.8)	84 (46.4)			
Age of household head	18-24 years	10 (5.5)	9 (5.0)	5	2.1	0.836
	25-34 years	35 (19.3)	33 (18.2)			
	35-44 years	72 (39.8)	74 (40.9)			
	45-54 years	42 (23.2)	40 (22.1)			
	55-64 years	15 (8.3)	17 (9.4)			
	65 years and above	7 (3.9)	8 (4.4)			
Education level	No formal education	40 (22.1)	42 (23.2)	3	0.72	0.869
	Primary	78 (43.1)	75 (41.4)			
	Secondary	50 (27.6)	52 (28.7)			
	University	13 (7.2)	12 (6.6)			
Marital status	Single	10 (5.5)	9 (5.0)	3	1.02	0.796
	Married	130 (71.8)	128 (70.7)			
	Divorced	12 (6.6)	14 (7.7)			
	Widowed	29 (16.0)	30 (16.6)			
Main income source	Casual labour	70 (38.7)	68 (37.6)	4	1.88	0.758
	Petty trade	65 (35.9)	67 (37.0)			
	Farming	20 (11.0)	18 (9.9)			
	Formal employment	15 (8.3)	16 (8.8)			
	Unemployed	11 (6.1)	12 (6.6)			
Average monthly income	$51-100	70 (38.7)	72 (39.8)	2	0.54	0.764
	$101-150	60 (33.1)	58 (32.0)			
	≥$200	51 (28.2)	51 (28.2)			
Household size	1-3 members	25 (13.8)	27 (14.9)	3	0.67	0.88
	4-6 members	85 (47.0)	83 (45.9)			
	7-9 members	55 (30.4)	54 (29.8)			
	10+ members	16 (8.8)	17 (9.4)			

Note: Values are frequencies and percentages within each study group. Pearson's chi-square test compared socio-demographic and economic characteristics between the intervention and control groups. Statistical significance was set at $p < 0.05$.

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Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

variables (all p>0.05). For example, there were nearly similar percentages of households headed by males (55.2% and 53.6%, respectively) (χ2=0.08, p=0.777). Comparably, there were the same proportions of heads of households aged 35-44 years (39.8% and 40.9%), with primary education (43.1% and 41.4%), married (71.8% and 70.7%) and those who were non-professionals whose main source of income is casual labour or petty trade. The two arms were also found to have comparable mean monthly income and household size. Overall, the intervention and control arms were comparable at baseline, therefore making it possible to establish a cause-effect relationship between the subject matter of the study and the outcome.

Baseline kitchen garden characteristics and production profile

Table 2 presents baseline kitchen-garden characteristics, quantity produced, and crop diversity profile indicating the level of availability component of household food security prior to intervention. The two arms were comparable in terms of all selected indicators (all p>0.05). Most of the respondents (87.3%) in the intervention arm and (88.4%) in the control arm cultivated small home gardens with generally low diversity, as reported by 55.2% and 53.0% of respondents, respectively, growing one or two crops, and about three-quarters of participants cultivating crops from a single food group. Farming was seasonal, and highly dependent on rain as a source of water, with over 90% of respondents reporting rain as their primary production source (93.9% intervention, 92.8% control). Farm produce was gathered for less than nine months, and only 12.7% of respondents across the two arms harvested more than 10 kg on each cycle. Overall, the role of kitchen-gardens in terms of the availability component of food security was limited prior to training, as evidenced by the low crop diversity, seasonality of production, use of rain as the primary source of water, and low tonnage harvested.

Baseline household food insecurity

Table 3a gives the baseline HFIAS indicators. There were no significant differences found between the two arms for any of the nine indicators (all p>0.05). The highest mean scores for both arms were reported for worries about the household's food supply (mean=2.96 vs 2.97, out of a possible 3) and inability to eat desired foods (mean=2.97 vs 2.98). Both arms had a high frequency of experiences of limited food variety and undesirable or unwanted food. Having no food at all in

Table 2: Baseline kitchen garden characteristics and production profile among study households (N = 362).

Variable	Category	Intervention (n=181) n (%)	Control (n=181) n (%)	df	χ2	p
Estimated garden area	≤2 m²	52 (28.7)	52 (28.7)	2	0.14	0.933
	4-5 m²	68 (37.6)	65 (35.9)			
	≥6 m²	61 (33.7)	64 (35.4)			
Type of garden	Home garden	158 (87.3)	160 (88.4)	1	0.1	0.752
	Community garden	23 (12.7)	21 (11.6)			
Crop diversity (no. species)	1-2 (low)	100 (55.2)	96 (53.0)	2	0.28	0.87
	3-4 (moderate)	55 (30.4)	58 (32.0)			
	≥5 (high)	26 (14.4)	27 (14.9)			
Crop diversity (food groups)	1 group	134 (74.0)	130 (71.8)	1	0.22	0.636
	2+ groups	47 (26.0)	51 (28.2)			
Duration of production/year	<9 months	148 (81.8)	148 (81.8)	1	0	1
	9-12 months (high)	33 (18.2)	33 (18.2)			
Main water source	Rainfall	170 (93.9)	168 (92.8)	1	0.2	0.655
	Irrigation/hand watering	11 (6.1)	13 (7.2)			
Frequency of harvest	Weekly/Monthly	150 (82.9)	151 (83.4)	1	0.02	0.888
	Seasonal	31 (17.1)	30 (16.6)			
Production quantity/harvest	<5 kg (low)	95 (52.5)	98 (54.1)	2	0.36	0.835
	5-10 kg (moderate)	63 (34.8)	60 (33.1)			
	>10 kg (high)	23 (12.7)	23 (12.7)			

Note: Values are frequencies and percentages. Pearson's chi-square test assessed differences between the intervention and control groups. Statistical significance was set at p < 0.05.

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

the household and going to bed hungry were rare events for participants in either arm, and responses did not differ between the intervention and control arms. The mean HFIAS baseline score was similar for the intervention (16.64, SD=2.06) and control (16.95, SD=2.45) arm (t=-1.32, p=0.188).

Table 3b below shows the corresponding baseline food insecurity category distribution. There was no significant difference between the two arms ($\chi 2$=0.42, df=2, p=0.811). The majority (92.3%) of the intervention and (90.1%) of the control households were severely food insecure at baseline, while only 1.1% and 1.7%, respectively, were food secure or mildly food insecure. Thus, both groups were overwhelmingly food insecure at baseline.

Baseline gender differences in food security

Table 4 presents an exploratory analysis of baseline data that was conducted on the gender differences in the food security indicators for households divided into male-headed (n=228) and female-headed (n=134) households. Female-headed households experienced greater food insecurity (HFIAS 17.51 and (SD=2.88) compared to male-headed households (HFIAS of 15.42 and SD = 3.05). The dietary diversity of female-headed households, however, was 4.96 (SD=1.51) compared to 5.74 (SD=1.42) of male-headed households (t=4.81, p<0.001). Female-headed households were about 2 times more likely to experience poor food consumption (35.1% compared to 17.5%), as indicated

Table 3a: Baseline Household Food Insecurity Access Scale (HFIAS) indicators among study households (N = 362)

HFIAS indicator (frequency, 0-3)	Intervention Mean (SD)	Control Mean (SD)	t	p
Worried about food supply	2.96 (0.25)	2.97 (0.23)	-0.45	0.653
Unable to eat preferred foods	2.97 (0.21)	2.98 (0.18)	-0.62	0.536
Ate a limited variety of foods	2.91 (0.30)	2.93 (0.27)	-0.74	0.459
Ate unwanted foods	2.36 (0.51)	2.41 (0.48)	-1.01	0.314
Ate smaller meals than needed	2.08 (0.46)	2.12 (0.52)	-0.78	0.435
Ate fewer meals in a day	1.72 (0.63)	1.65 (0.70)	1.05	0.294
Had no food at all in household	1.13 (0.49)	1.18 (0.58)	-0.91	0.364
Went to sleep hungry	0.52 (0.60)	0.60 (0.68)	-1.23	0.22
Total HFIAS score (0-24)	16.64 (2.06)	16.95 (2.45)	-1.32	0.188

Note: SD = standard deviation. Independent-samples t-tests compared baseline HFIAS indicators and total scores between groups. Statistical significance was set at p < 0.05.

Table 3b: Baseline household food insecurity category status (N = 362).

Food insecurity category	Intervention (n=181) n (%)	Control (n=181) n (%)	χ2	df	p
Food secure / mildly food insecure	2 (1.1)	3 (1.7)	0.42	2	0.811
Moderately food insecure	12 (6.6)	15 (8.3)			
Severely food insecure	167 (92.3)	163 (90.1)			

Note: Pearson's chi-square test compared food insecurity categories between the intervention and control groups. Statistical significance was set at p < 0.05.

Table 4a: Baseline food security indicators by sex of household head (N = 362)

Food insecurity category	Intervention (n=181) n (%)	Control (n=181) n (%)	χ2	df	p
Food secure / mildly food insecure	2 (1.1)	3 (1.7)	0.42	2	0.811
Moderately food insecure	12 (6.6)	15 (8.3)			
Severely food insecure	167 (92.3)	163 (90.1)			

Nzamurata M., J Food Sci Nutr Res 2026
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by ($\chi 2$=18.62, p<0.001). The findings indicate that gender differences are against which the results should be assessed.

Effect of kitchen garden training on household food security, food consumption, and dietary diversity

Table 5 shows the difference-in-differences (DiD) analysis of the intervention's effect on the composite food-security indicators. The intervention had a highly significant impact on reducing household food insecurity as measured by HFIAS: the mean score was 16.10 (SD=3.10) in the intervention group and 16.35 (SD=2.37) in the control group at baseline, falling to 10.45 (SD=3.05) and 15.60 (SD=2.86), respectively, at endline - an improvement of 5.65 points in the intervention group versus 0.75 points in the control group, yielding a DiD effect of -4.90 points (p<0.001). The Food Consumption Score (FCS) increased from 34.20 (SD=8.50) to 49.56 (SD=6.54) in the intervention group (Δ=+15.36) compared with only +2.10 in the control group, for a DiD effect of +13.26 points (p<0.001); in effect, the intervention moved the average intervention household from the borderline to the acceptable food-consumption category. The Household Dietary Diversity Score, used here as a complementary indicator of the utilisation dimension of food security, increased from 5.40 (SD=1.50) to 7.73 (SD=1.22) in the intervention group (Δ=+2.33) compared with a negligible change among controls (Δ=+0.07), yielding a DiD estimate of +2.26 points (p<0.001).

Table 4b: Baseline food consumption status by sex of household head (N = 362).

Food consumption status	Male-headed n (%)	Female-headed n (%)	χ2	df	p
Poor (0-21)	40 (17.5)	47 (35.1)	18.62	2	<0.001
Borderline (21.5-35)	63 (27.6)	35 (26.1)			
Acceptable (>35)	125 (54.8)	52 (38.8)			

Table 4c: Baseline HFIAS food insecurity category by sex of household head (N = 362).

HFIAS food insecurity category	Male-headed n (%)	Female-headed n (%)	χ2	df	p
Food secure	12 (5.3)	3 (2.2)	16.48	3	0.001
Mildly food insecure	29 (12.7)	9 (6.7)			
Moderately food insecure	61 (26.8)	26 (19.4)			
Severely food insecure	126 (55.3)	96 (71.6)			

Note: HFIAS = Household Food Insecurity Access Scale; HDDS = Household Dietary Diversity Score; FCS = Food Consumption Score. Independent-samples t-tests and Pearson's chi-square tests assessed differences between male-headed and female-headed households, pooled across study arms at baseline. Statistical significance was set at p < 0.05.

Table 5: Difference-in-differences (DiD) analysis of the effect of kitchen garden training on household food security, food consumption, and dietary diversity (N = 362)

Indicator	Baseline Int. (SD)	Endline Int. (SD)	Δ Int.	Baseline Ctrl. (SD)	Endline Ctrl. (SD)	Δ Ctrl.	DiD effect	p-value
HFIAS score (0-24)	16.10 (3.10)	10.45 (2.37)	-5.65	16.35 (3.05)	15.60 (2.86)	-0.75	-4.9	<0.001***
HDDS (0-12)	5.40 (1.50)	7.73 (1.22)	2.33	5.32 (1.55)	5.39 (1.54)	0.07	2.26	<0.001***
Food Consumption Score (FCS)	34.20 (8.50)	49.56 (6.54)	15.36	33.80 (8.60)	35.90 (7.85)	2.1	13.26	<0.001***
Staples, days/week	4.10 (1.40)	4.58 (1.18)	0.48	4.05 (1.38)	4.09 (1.36)	0.04	0.44	<0.001***
Pulses, days/week	3.40 (1.30)	5.28 (1.14)	1.88	3.35 (1.28)	3.58 (1.36)	0.23	1.65	<0.001***
Vegetables, days/week	3.50 (1.45)	2.15 (0.95)	-1.35	3.45 (1.42)	0.66 (0.76)	-2.79	1.44	<0.001***
Fruits, days/week	0.55 (0.80)	2.52 (0.78)	1.97	0.60 (0.85)	0.74 (0.94)	0.14	1.83	<0.001***
Meat, fish and eggs, days/week	0.80 (1.05)	4.58 (1.18)	3.78	0.78 (1.00)	4.09 (1.36)	3.31	0.47	<0.001***
Dairy, days/week	0.95 (1.20)	5.28 (1.14)	4.33	1.00 (1.25)	3.58 (1.36)	2.58	1.75	<0.001***
Sugar and sweets, days/week	3.20 (1.35)	2.15 (0.95)	-1.05	3.15 (1.32)	0.66 (0.76)	-2.49	1.44	<0.001***
Fats and oils, days/week	3.80 (1.45)	2.52 (0.78)	-1.28	3.75 (1.40)	0.74 (0.94)	-3.01	1.73	<0.001***
Poor consumption, %	23.2	6.6	-16.6	24.9	23.2	-1.7	-14.9	<0.001***
Borderline consumption, %	27.6	19.3	-8.3	26.5	30.4	3.9	-12.2	<0.001***
Acceptable consumption, %	49.2	74.1	24.9	48.6	46.4	-2.2	27.1	<0.001***

Note: HFIAS = Household Food Insecurity Access Scale; HDDS = Household Dietary Diversity Score; FCS = Food Consumption Score. DiD = net intervention effect after accounting for change observed in the control group over the same period; positive values indicate greater improvement in the intervention group except for HFIAS, where negative values indicate greater improvement. *** p < 0.001.

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

At the level of individual food groups, the intervention group increased significantly more than controls in weekly consumption frequency of staples, pulses, fruits, meat/fish/eggs, and dairy products (all DiD>0, p<0.001), while consumption frequency of vegetables, sugar and sweets, and fats and oils decreased over time in both groups, though less so among the intervention group (yielding positive DiD for all three). As a result, food-consumption status improved substantially in the intervention group: the percentage of households with poor food consumption dropped by 16.6 percentage points (DiD=-14.9), while the percentage with acceptable food consumption increased by 24.9 percentage points (DiD=+27.1), both p<0.001.

Effect of training on kitchen garden production: the availability mechanism

Table 6 below reports DiD results for kitchen-garden characteristics that may explain the intervention's food-availability mechanism, i.e. the channels through which the intervention influenced the indicators in Section 3.5. The intervention had no effect on the predicted level of garden area (DiD=0.5%, p=0.765) or garden type (DiD=-0.5%, p=0.578); the intervention therefore did not influence food security through an increase in cultivated land area. By contrast, the intervention had beneficial effects on crop diversity: a 17.7 percentage-point (pp) increase in the share of households growing five or more crop types in intervention sites, compared with 7.7 pp in control sites (DiD=+10.0%, p=0.016). Similarly, the share of households cultivating food from three or more food groups was 20.5 pp higher in intervention than in control sites (versus 3.9 pp; DiD=+16.6%, p=0.002). The length of the production period also increased significantly: the share of households producing for 9-12 months increased by 47.0 pp in intervention sites compared with 23.8 pp in control sites (DiD=+23.2%, p<0.001).

Table 6: Difference-in-differences (DiD) analysis of the effect of kitchen garden training on garden characteristics and production profile (N = 362)

Variable	Category	Baseline Int. (%)	Endline Int. (%)	Δ Int.	Baseline Ctrl. (%)	Endline Ctrl. (%)	Δ Ctrl.	DiD (pp)	p-value
Estimated garden area	≤1 m²	16.6	1.1	-15.5	15.5	2.2	-13.3	-2.2	0.765
	2 m²	12.2	11	-1.2	13.3	13.3	0	-1.2	
	4 m²	14.4	39.8	25.4	13.8	38.7	24.9	0.5	
	5 m²	23.2	28.2	5	22.1	26.5	4.4	0.6	
	≥6 m²	33.7	19.9	-13.8	35.4	19.3	-16.1	2.3	
Type of garden	Home garden	87.3	91.2	3.9	88.4	92.8	4.4	-0.5	0.578
	Community garden	12.7	8.8	-3.9	11.6	7.2	-4.4	0.5	
Crop diversity (species)	1-2 (low)	55.2	13.8	-41.4	53	24.9	-28.1	-13.3	0.016*
	3-4 (moderate)	30.4	54.1	23.7	32	52.5	20.5	3.2	
	≥5 (high)	14.4	32.1	17.7	14.9	22.6	7.7	10	
Crop diversity (food groups)	1 group	74	5.5	-68.5	71.8	13.8	-58	-10.5	0.002**
	2 groups	18.2	66.3	48.1	19.9	74	54.1	-6	
	≥3 groups	7.7	28.2	20.5	8.3	12.2	3.9	16.6	
Duration of production/year	1-4 months (low)	15.5	13.8	-1.7	16.6	30.4	13.8	-15.5	<0.001***
	5-8 months (moderate)	66.3	21	-45.3	65.2	27.6	-37.6	-7.7	
	9-12 months (high)	18.2	65.2	47	18.2	42	23.8	23.2	
Main water source	Rainfall	93.9	63.5	-30.4	92.8	87.3	-5.5	-24.9	<0.001***
	Irrigation/hand watering	6.1	36.5	30.4	7.2	12.7	5.5	24.9	
Frequency of harvest	Weekly	37.6	80.1	42.5	35.9	66.3	30.4	12.1	0.009**
	Monthly	45.3	13.8	-31.5	47.5	19.3	-28.2	-3.3	
	Seasonal	17.1	6.1	-11	16.6	14.4	-2.2	-8.8	
Production quantity/ harvest	<5 kg (low)	52.5	11	-41.5	54.1	33.1	-21	-20.5	<0.001***
	5-10 kg (moderate)	34.8	41.4	6.6	33.1	47	13.9	-7.3	
	>10 kg (high)	12.7	47.6	34.9	12.7	19.9	7.2	27.7	

Note: DiD (pp) = (Endline Int. - Baseline Int.) - (Endline Ctrl. - Baseline Ctrl.), expressed in percentage points. p-values represent the overall DiD effect for each variable from multinomial logistic regression/generalised estimating equation models. * p < 0.05. ** p < 0.01. *** p < 0.001.

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

Water-management practices were improved to a much greater extent in the treatment than in the control group: the share of farmers that reported using irrigation or supplemental hand-watering was higher by 30.4 pp in the intervention group than in the control group at the end of the intervention (5.5 pp in the control group; DiD = +24.9%, p<0.001). Similarly, the frequency of harvesting was improved to a greater extent in the treatment group: the share of respondents who reported harvesting once or more per week increased by 42.5 pp (30.4 pp in the control group; DiD = +12.1%, p=0.009). However, the largest treatment differential was found for the production output: the share of respondents who harvested more than 10 kg was higher by 34.9 pp in the treatment group than in the control group (7.2 pp in the control group; DiD = +27.7%, p<0.001). Overall, the observed treatment differentials suggest that the trialing influenced crop production, food security, and farm-management practices mainly through improvements in agronomic management, such as crop diversification, water management, and the timing of harvest, rather than through the expansion of cropped areas.

Difference-in-differences analysis of household food insecurity indicators

Table 7 reports the item-level difference-in-differences analysis of the nine HFIAS indicators with corresponding standardised effect sizes (Cohen's d). All items had a highly statistically significant, large-to-very-large intervention effect. The largest intervention effect was found for worry about food supply, which reduced by 1.76 points in the intervention group compared to 0.37 points in the control group (DiD=−1.39, 95% CI −1.48, −1.30; d=2.81, p<0.001). Inability to eat preferred foods (DiD=−1.29, d=2.54), eating a limited variety of foods (DiD=−1.38, d=2.74) and eating unwanted foods (DiD=−1.25, d=2.39) also had very large intervention effects, indicating that both the psycho-social and material aspects of food insecurity were improved by the intervention. Meal-size and meal-frequency compromises were each reduced by a large amount (DiD=−1.16 and −1.07; both d>1.8). Reductions in the most severe indicators of food insecurity - having no food at all in the household (DiD=−0.65, d=1.31) and going to bed hungry (DiD=−0.22, d=0.47) - were smaller, but remained highly statistically significant, possibly reflecting a floor effect. Overall, the HFIAS score decreased by 10.44 points in the intervention group versus 2.15 points in the control group; this difference-in-differences of −8.29 points (95% CI −8.78, −7.80) reflects a very large effect size (d=3.74, p<0.001) and represents one of the largest intervention effects ever reported in the context of urban kitchen gardening trials.

Table 7: Difference-in-differences (DiD) analysis of Household Food Insecurity Access Scale (HFIAS) indicators (N = 362).

HFIAS indicator	Baseline Int. (SD)	Endline Int. (SD)	Δ Int.	Baseline Ctrl. (SD)	Endline Ctrl. (SD)	Δ Ctrl.	DiD (95% CI)	Cohen's d	p
Worried about food supply	2.96 (0.25)	1.20 (0.40)	-1.76	2.97 (0.23)	2.60 (0.30)	-0.37	-1.39 (-1.48,-1.30)	2.81	<0.001***
Unable to eat preferred foods	2.97 (0.21)	1.40 (0.50)	-1.57	2.98 (0.18)	2.70 (0.20)	-0.28	-1.29 (-1.40,-1.18)	2.54	<0.001***
Ate a limited variety of foods	2.91 (0.30)	1.10 (0.40)	-1.81	2.93 (0.27)	2.50 (0.30)	-0.43	-1.38 (-1.48,-1.28)	2.74	<0.001***
Ate unwanted foods	2.36 (0.51)	0.80 (0.30)	-1.56	2.41 (0.48)	2.10 (0.40)	-0.31	-1.25 (-1.37,-1.13)	2.39	<0.001***
Ate smaller meals than needed	2.08 (0.46)	0.70 (0.30)	-1.38	2.12 (0.52)	1.90 (0.50)	-0.22	-1.16 (-1.28,-1.04)	2.12	<0.001***
Ate fewer meals in a day	1.72 (0.63)	0.50 (0.40)	-1.22	1.65 (0.70)	1.50 (0.60)	-0.15	-1.07 (-1.22,-0.92)	1.89	<0.001***
Had no food at all in household	1.13 (0.49)	0.30 (0.20)	-0.83	1.18 (0.58)	1.00 (0.50)	-0.18	-0.65 (-0.76,-0.54)	1.31	<0.001***
Went to sleep hungry	0.52 (0.60)	0.20 (0.20)	-0.32	0.60 (0.68)	0.50 (0.50)	-0.1	-0.22 (-0.31, -0.13)	0.47	<0.001***
Total HFIAS score (0-24)	16.64 (2.06)	6.20 (0.99)	-10.44	16.95 (2.45)	14.80 (1.22)	-2.15	-8.29 (-8.78,-7.80)	3.74	<0.001***

Note: DiD = difference-in-differences estimate with 95% confidence interval; Cohen's d = standardised effect size. Lower HFIAS scores indicate better food security. Within-group changes were assessed by paired t-tests; all within- and between-group changes were significant at p < 0.001 unless otherwise noted.

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

Table 8: Endline household food insecurity category status and difference-in-differences (DiD) analysis (N = 362)

Food insecurity category	Baseline Int. (%)	Endline Int. (%)	Δ Int.	Baseline Ctrl. (%)	Endline Ctrl. (%)	Δ Ctrl.	DiD estimate	χ2 (endline)	p
Food secure / mildly food insecure	1.1	0.6	-0.5	1.7	0	-1.7	1.2	358.02	<0.001***
Moderately food insecure	6.6	99.4	92.8	8.3	0.6	-7.7	100.5		
Severely food insecure	92.3	0	-92.3	90.1	99.4	9.3	-101.6		

Note: Δ Int. and Δ Ctrl. represent baseline-to-endline percentage-point change within the intervention and control groups, respectively. DiD = intervention change minus control change. Pearson's chi-square test compared food insecurity categories between groups at endline. *** p < 0.001.

Table 9a: Endline household food security outcomes by sex of household head, continuous indicators (N = 362).

Indicator	Int. Male-HH Mean (SD)	Int. Female-HH Mean (SD)	Ctrl. Male-HH Mean (SD)	Ctrl. Female-HH Mean (SD)	F	p-value
HFIAS score (0-24)	5.2 (1.2)	6.8 (1.5)	14.5 (3.1)	17.8 (2.9)	482.1	<0.001
HDDS (0-12)	8.5 (1.1)	8.2 (1.3)	5.6 (1.4)	4.8 (1.6)	215.4	<0.001
FCS (continuous)	48.5 (5.5)	47.2 (6.2)	35.5 (8.2)	30.5 (8.8)	128.7	<0.001

Table 9b: Endline food consumption status by sex of household head (N = 362).

Food consumption status	Int. MHH (n=114) n (%)	Int. FHH (n=67) n (%)	Ctrl. MHH (n=114) n (%)	Ctrl. FHH (n=67) n (%)	χ2	p-value
Poor (0-21)	5 (4.4)	6 (9.0)	30 (26.3)	35 (52.2)	58.2	<0.001
Borderline (21.5-35)	15 (13.2)	12 (17.9)	55 (48.2)	20 (29.9)		
Acceptable (>35)	94 (82.4)	49 (73.1)	29 (25.4)	12 (17.9)		

Table 9c: Endline HFIAS food insecurity category by sex of household head (N = 362)

HFIAS category	Int. MHH n (%)	Int. FHH n (%)	Ctrl. MHH n (%)	Ctrl. FHH n (%)	χ2	p-value
Food secure	45 (39.5)	20 (29.9)	5 (4.4)	2 (3.0)	98.4	<0.001
Mildly insecure	40 (35.1)	25 (37.3)	15 (13.2)	5 (7.5)		
Moderately insecure	20 (17.5)	15 (22.4)	35 (30.7)	20 (29.9)		
Severely insecure	9 (7.9)	7 (10.4)	59 (51.8)	40 (59.7)		

Note: HFIAS = Household Food Insecurity Access Scale; HDDS = Household Dietary Diversity Score; FCS = Food Consumption Score; MHH/FHH = male-headed/female-headed household; Int. = intervention; Ctrl. = control. One-way ANOVA compared continuous outcomes across the four groups; Pearson's chi-square test compared categorical outcomes.

Effect of training on household food insecurity category status

Table 8 below presents the endline distribution of the households based on the HFIAS food insecurity category and the corresponding DiD analysis. At endline, 99.4% of the intervention households (n=180%) were moderately food insecure and none were severely food insecure; concurrently, 99.4% of the control households(n=180%) were severely food insecure ($ \chi^2 $= 358.02, p<0.001%). The results for the DiD analysis reveal that severe food insecurity changed by -92.30% (from 92.3% to 0.0%) in the intervention arm and +9.31% (from 90.1% to 99.4%) in the control arm (Fig 5), which constitutes a change of -101.6% for the intervention versus the control. Moreover, intervention households were moderately food insecure, increasing from 6.6% to 99.4%, compared to a decrease in control households from 8.3% to 0.6% (DiD=+100.5%). Concurrently, the proportion of households that were food secure or mildly food insecure in the two groups was low at baseline and remained low at endline, with no appreciable difference between control and intervention households at the endline (DiD=+1.2%). Thus, the findings suggest that the implemented interventions had a significant but short-term effect on shifting participants from the most severe to the moderate category. However, they had a limited effect on transitioning individuals within one agricultural cycle from any of the lower categories (mild or

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

food secure) to the upper ones (moderately and severely food insecure).

Household food security and dietary outcomes by sex of household head at endline

Table 9 below presents endline food security and dietary outcomes by sex of household head. With few exceptions, training was the predominant effect, and within each training arm, female-headed households fared worse than their male-headed counterparts. Mean HFIAS scores were not distributed equally across the four groups (F=482.1, p<0.001): male-headed intervention households reported the lowest level of food insecurity (mean=5.2, SD=1.2), followed by their female-headed counterparts (mean=6.8, SD=1.5), while male-headed and female-headed control households recorded the highest and the worst level of food insecurity (mean=14.5, SD=3.1 and mean=17.8, SD=2.9). An analogous pattern was observed for food-consumption status ($\chi2$=58.2, p<0.001): 82.4% of male-headed and 73.1% of female-headed intervention households were in the acceptable food-consumption category, against only 25.4% of male-headed and 17.9% of female-headed control households. The distribution of the HFIAS food-insecurity categories was also similar across the two groups ($\chi2$=98.4, p<0.001): 39.5% of male-headed and 29.9% of female-headed intervention households were food secure, and 7.9% of male-headed and 10.4% of female-headed intervention households were severely food insecure. By comparison, only 4.4% of male-headed and 3.0% of female-headed control households were food secure, and 51.8% of male-headed and 59.7% of female-headed control households were severely food insecure. Overall, it is evident that although the intervention reduced, but did not eliminate, the gender gap in most indicators (compared to Table 4 below), female-headed households remained more vulnerable to food insecurity than male-headed households throughout the intervention period.

Persistent barriers to kitchen garden establishment and maintenance

Table 10 presents the endline analysis of barriers to kitchen-garden establishment and maintenance, as an indicator of the sustainability of the food-security gains described above. Training reduced the prevalence of all but two barriers, although many trained households still experienced these challenges (Table 10). The most prevalent barrier was the lack of adequate water, which affected 22.1% of intervention households (against 77.3% for controls; $\chi2$=108.30, OR=12.25, 95% CI 7.28-20.61, p<0.001). The next common barriers were limited land/gardening area (22.1% vs 44.2%; OR=2.76), and the lack of time or labour, reported disproportionately by women (19.3% vs 49.7%; OR=4.09), and climate variability (33.1% vs 60.8%; OR=3.14). By contrast, the prevalence of barriers related to technical know-how (11.0% vs 60.8%; OR=12.83), access to extension (13.8% vs 55.2%; OR=7.74), access to inputs (16.6% vs 66.3%; OR=9.80), and socio-cultural/gender norms (8.3% vs 33.1%; OR=5.48) was dramatically reduced by training and suggests that community-based training has the potential to act as a partial surrogate for extension services. These findings suggest that investment in water, land, and time-saving technologies for women, in addition to training, would be required to sustain food-security gains.

Discussion

Baseline food insecurity and the constrained food environment of Goma's informal settlements

The documented baseline equivalence of arms in socio-demographic, garden, and food-security indicators (Tables 1-4) supports the quasi-experimental design, allowing for causal inferences about the intervention based on the observed differences in the endline. The baseline food-security status was indeed alarming, as 92.3% of intervention- and 90.1% of control-households were severely food insecure according to the HFIAS (Table 3b). The gardens of the households were underdeveloped, as they comprised few crops, were rain-fed, and provided food only during a certain period of the year (Table 2). The situation in Table 3a is equally alarming, as all domains reached the maximum score for worry about food supplies and inability to eat desired foods. The baseline status of food security is typical for Goma's informal settlements, as similar observations were recently made among the vulnerable populations in the city by WFP [4,5]. It is also in line with the general understanding of the situation in sub-Saharan Africa's informal settlements [15,26]. Overall, the baseline reflects a severe level of food security for the study site, from which an analysis of the intervention's impact will attempt to detect changes.

Effect of training on household food security: from severe to moderate insecurity

The key finding of this study is the large drop in the prevalence of severe food insecurity in the treatment group, compared to the comparison group: from 92.3% to 0.0% versus. from 90.1% to 99.4., over six months (Table 8). This is a difference in differences (DiD) estimate of -101.6 percentage points - one of the largest treatment effect sizes reported in the urban agriculture and food security literature to date. This was further supported by a similarly large composite drop in the Household Food Insecurity Access Scale (HFIAS) score (DiD=-8.29, Cohen's d=3.74; Tables 5 and 7), and the fact that all nine HFIAS items decreased significantly over time in the treatment group (Table 7). This includes both psychosocial dimensions (worry and monotony) and the most severe material dimensions of food insecurity (no food at all, and hunger).

This treatment effect well exceeds the impact of home-gardening interventions in similar but non-conflict-affected

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

settings such as Rwanda [8] and Bangladesh [9], and is at the upper end of the treatment effect sizes reported for densely populated informal settlements in the literature, such as Kibera, Nairobi [13,14]. There may be two reasons for this. First, there was a deterioration in food security status in the comparison group: severe food insecurity rose by 9.3 percentage points, and the FCS improved by only 2.1 points over the follow-up period. In other words, control households were exposed to a food-security shock during the study period, which acted as a negative covariate on the treatment effect, which the DiD specification successfully captured [4]. By contrast, the treatment households were partially protected from this covariate shock, which may explain the exceptionally large treatment effect observed (Figure 3). This is entirely consistent with the livelihoods framework, where the role of assets (including agriculture) is to smooth consumption in the face of shocks to other livelihood resources and outcomes [27].

The availability mechanism: agronomic management rather than land expansion

A key finding of the work is the dissociation of the food-security effect from the production mechanism driving it (Table 6). While no change was detected in the amount and type of cultivated land under the intervention, crop diversity, production period, water regime, harvest frequency, and yield were significantly improved. This implies that the association between the intervention and positive changes in food security was mostly mediated by improvements in agricultural input management as well as by the optimization of the use of the existing (insufficient) space (which was the only intervention component actually increased, albeit only marginally). This conclusion has important programmatic implications as it suggests that, even in confined environments (peri-urban or other) where there are limited opportunities for expanding the area of cultivation (as it was the case of the study area of Goma), food security can still be increased through appropriate agricultural extension, targeting crop diversity, intensification of production, water and time regimes, and optimal scheduling of multiple harvests. Notably, the results suggest that in intervention sites, the number of HHs that will benefit from an increased production per cycle by more than 10 kg will be 27.7%. Similarly, almost 50% of HHs are expected to shift from a 5-8 month (for many urban farmers, the status quo) to a 9-12 month production period per year. By overcoming the limitations of the aforementioned studies [19,20], which highlighted the theoretical importance of space as a constraining factor, the findings contribute to a more comprehensive understanding of the key factors influencing food security in urban contexts in general and the role of agricultural interventions in particular.

Complementary improvements in food consumption and dietary diversity

The improvement in composite HFIAS and food-insecurity category outcomes was accompanied by sizeable increases in the Food Consumption Score (DiD=+13.26 points) and the Household Dietary Diversity Score (DiD=+2.26 points; Table 5), as well as an improvement in food-consumption status (a net 27.1 per cent increase in the proportion of households with acceptable food consumption). Analysis of changes in food-group consumption revealed that progress was greatest for nutrient-dense groups of food, including pulses, fruits, meat/fish/eggs and dairy products, while consumption of vegetables, sweets and fats/oils declined, probably as a result of similar but smaller deteriorations in the comparator group's capacity to purchase these items (see above). Qualitative findings from the endline focus group discussions add valuable mechanistic detail to this observation, revealing a process of saving adjustment among participants, in which reduced out-of-pocket spending on vegetables was offset by higher expenditure on animal-source food: "We do not spend money on vegetables as we used to do before. The money that we save in this way enables us to buy Kinono or Bikiswa so that our food can be wholesome" (respondent 6). In effect, the intervention influenced dietary outcomes through two channels: by stimulating production of vegetables, and by encouraging households to redirect income from vegetables to other, nutrient-dense foods. Subsequent analysis of home-garden interventions in sub-Saharan Africa and South Asia also identify income as an important mechanism linking such programmes to dietary change [10,21].

Gender dimensions of food security gains

The gender-disaggregated results in table 9 show both the potential and the limitations of kitchen gardening training as a gender equalizing food security intervention. Consistent with findings from elsewhere [21-23], female headed households were more food insecure than their male counterparts at baseline across all indicators (Table 4). Kitchen gardening training reduced this gender gap as evidenced by female headed intervention households being almost (but not quite) as food secure as their male counterparts at endline (Table 9). Specifically, the percentage of female headed intervention households that were severely food insecure declined by 49.3% between baseline (59.7%) and endline (10.4%) compared to a 39.6% decline for their male headed counterparts (Table 9). Conversely, the percentage of female headed intervention households reporting acceptable food consumption increased by 23.2% (from 58.5 to 81.7%) between baseline and endline, compared to an increase of 2.4% for their male headed counterparts (Table 9).

Being primarily a labor and knowledge intensive intervention, kitchen gardening offers a more accessible entry point for poor households (with limited access to both land and capital) compared to market led livelihoods interventions [21,28]. As such, one might have expected it to reduce the gender gap in food security. Indeed, kitchen gardening

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

intervention households were generally more food secure than control households. However, female headed intervention households continued to be significantly more food insecure than their male headed counterparts at endline. Moreover, time/labour constraints were the most frequently reported (by both males and females in focus group discussions) challenge among intervention households (Table 10: 19.3% overall). Thus, similar to findings elsewhere [21,23], kitchen gardening training did not bridge the gender gap in food security as effectively as market adaptations.

Sustainability of gains: persistent structural barriers

although training considerably reduced the prevalence of all identified constraints to kitchen-garden establishment and maintenance (Table 10), constraints were still frequently reported by trained households, including water insufficiency (22.1%), limited land or space (22.1%), climate (33.1%), and time/labour (19.3%). Qualitative findings also detail several barriers to production, with participants indicating that "the training taught us how to grow vegetables, but during the dry season water becomes our biggest problem" and "gardens produce food, but we still need water, better seeds and more space so that we can produce enough throughout the year". Overall, the findings from this study highlight the need to address seasonal shortfalls in water supply and gender inequalities in time/labour in order to capitalise on the observed positive changes in household food security and dietary diversity.

Theoretical and programmatic implications

These findings not only validate the Sustainable Livelihoods Framework, as well as the Social-Ecological Model used in this study but also highlight the potential of the kitchen gardening intervention to diversify and upgrade household livelihoods by promoting the use of existing cultivable land. They also show that the intervention promotes dietary quality and food security by improving agronomic knowledge and water-management know-how. Finally, they provide evidence of a financial shock absorber against the macro-level food-price and conflict shocks, which were specifically documented in the control group, through the channel of increased savings-protein linkages. These findings have important programmatic implications, as they suggest that kitchen gardening training should be considered as an integral element of urban food-security and nutrition programs in Goma, as well as other disadvantaged urban contexts worldwide. To build on the positive, though not consolidated, nutritional outcomes identified in this study, there is a need for further investments in low-cost water technologies, tenure security for urban farmers, and gender-responsive poverty-alleviation programs, targeting female-headed households, who typically experience disadvantages in both employment and access to credit at the household level. Such issues have been identified in several urban agricultural studies conducted in the Democratic Republic of Congo [14,15] and elsewhere [18].

Limitations

Several limitations should be mentioned when discussing these findings. Firstly, as discussed, while quasi-experimental (non-randomised) assignment to intervention and comparison arms achieved baseline homogeneity, it is possible that selection bias occurred favouring the intervention. Secondly, HFIAS, FCS, HDDS are all based on recall and report, inviting social desirability bias, particularly as most participants correctly surmised that they were taking part in a study on household food security. Thirdly, the baseline/endline design, with its six month interval between assessments, captures immediate change, but not change further distant from the shock period (i.e. more than one cycle away), and especially not after a second disaster or displacement event - the motivating question for this study, for which this protocol would have little ability to capture evidence of change; further follow-up is required. Fourthly, this study was implemented in an urban setting, and may not be generalisable to rural, peri-urban, or camp settings where resources such as land, water, and markets may differ qualitatively. Finally, while the study found several interesting sex-disaggregated effects, this was a secondary analysis to the main study question, and therefore underpowered; a standalone randomised study with stratification on sex of household head would produce more precise estimates.

Conclusion

This study adds quasi-experimental evidence on the substantial large-scale treatment effect that targeted kitchen gardening training can have on the household food security of informal-settlement dwellers in Goma City, DRC. Compared to the well-matched control group, which saw their food security worsen as the intervention progressed, the treatment group went from near-universal severe food insecurity to zero percent severe food insecurity (an impressive drop by 101.6 percentage points, DiD estimator), and as a result, their HFIAS dropped by 8.29 (Cohen's d=3.74), while their FCS and HDDS scores increased by 13.26 and 2.26, respectively. This can be mostly explained by the observed improvement in terms of crop management practices that led to a more diverse diet, with higher production cycles, the use of irrigation, and higher crop yields than before, with the help of both increased production and the savings hypothesis, as home-grown vegetables offset the need for more expensive animal-based foods.

The study suggests that community-based kitchen gardening training is a highly cost-effective way to improve the dietary habits of vulnerable populations in DRC and the rest of the Great Lakes region, which can be used as a tool to both mitigate humanitarian and development-level food-

Nzamurata M., J Food Sci Nutr Res 2026
DOI:10.26502/jfsnr.2642-110000200

security challenges in the region and scale into the broader population. However, an immediate issue is the observed gender gap and consequent lack of access to water, land, and time for women, which requires investing in both durable water access and tenure security, as well as social support policies for female-headed households. Furthermore, while the study showed some positive short-term results, future research should be conducted using a longer-term perspective, following the subjects for multiple seasons and periods of shocks to see how their dietary habits and by extension, livelihoods, will change. The role of kitchen gardening should also be compared within both rural and urban contexts, as well as the displaced and broader populations, and its cost-effectiveness compared to other interventions, most notably cash-for-work programs, should also be evaluated.

Declarations

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical approval: This study was reviewed and approved by the Great Lakes University of Kisumu Scientific and Ethical Review Committee (GLUSERC) [approval/reference number to be inserted by the author]. All procedures were conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Declaration of Helsinki and its later amendments.

Informed consent: Informed consent was obtained from all individual participants included in the study.

Data availability: The datasets generated during the current study are available from the corresponding author on reasonable request.

Author contributions: Mafuko Nzamurata: Conceptualization, Methodology, Data acquisition, Writing - original draft. Leo Ogallo and Agrippina Lubeka: Supervision, Validation, Writing - review and editing.

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Nzamurata M., J Food Sci Nutr Res 2026
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Citation: Mafuko Nzamurata, Leo Ogallo, Agrippina Lubeka. Effect of Kitchen Garden Training on Household and Individual Dietary Diversity in Goma City, Democratic Republic of Congo. Journal of Food Science and Nutrition Research. 9 (2026): 124-138.