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RESEARCH ARTICLE

Impact of home gardens promoted among urban residents in Dhaka, Bangladesh

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Abstract

Promoting gardening among urban residents holds the potential to improve urban diets in low- and middle-income countries, but there is a lack of evidence of impact. This study tests the hypothesis that training urban residents in gardening increases their intake of fruit and vegetables. It uses panel data for 254 control and 425 treatment households from four city corporations in the Dhaka metropolitan area of Bangladesh. Urban residents, 85% of whom were women, were interviewed before the start of an urban gardening program and one year after training and inputs were provided to the treatment group. The study estimated the average treatment effects using a difference-in-difference estimator. Of the 38 outcomes tested, 20 are significant ($p < 0.05$) with 19 indicating a beneficial effect and one indicating an adverse effect. Among the beneficial effects, there is an increase in the diversity of fruits and vegetables produced (+5 species, $p < 0.01$), the frequency of harvesting (+0.64 times/week; $p < 0.01$), and increased sharing of produce with neighbors (+8%, $p < 0.01$). Regarding food and nutrition, there is an increase in women's dietary diversity score (+0.37 on a 0–10 scale; $p < 0.01$), women's minimum dietary diversity (+4%; $p < 0.01$), and in the number of portions of cooked vegetables eaten (+0.96 portions/day; $p < 0.01$). The gardening intervention also contributes to a range of perceived social, personal, and psychological benefits. The adverse effect is an increase in ultra-processed food consumption (+19%, $p = 0.04$). Nevertheless, the results confirm that urban gardening interventions can improve the quality of urban diets alongside other benefits.

Keywords Homestead food production · Kitchen garden · Fruit and vegetable · Urban agriculture · Difference-in-difference

1 Introduction

Approximately 80 percent of the world's population lives in urban and peri-urban areas (HLPE, 2024). Rural populations are drawn to cities in search of a better life. Metropolitan Dhaka, the fourth largest city on earth, had 10 million residents in 2000 but is expected to reach 25 million by 2025 (UN, 2018). Every year the city grows by about 320,000 people (Streatfield & Karar, 2008).

Globally, food insecurity is rapidly becoming an urban problem, with 77% of the world's moderately and severe food-insecure people living in urban and peri-urban areas (HLPE, 2024; see also Tuholske et al., 2020). Multiple forms of malnutrition – hunger, hidden hunger, and overnutrition – affect urban populations, exacerbated by a shift in diets towards increased consumption of ultra-processed foods and stagnant or declining consumption of nutritious fresh foods (Ameye, 2023; Popkin, 2014).

Fruit and vegetables are a food category essential for health but widely under-consumed. The World Health Organization recommends eating at least five portions or 400 g per day (WHO & FAO, 2003), but few people in low- and middle-income countries reach this (Frank et al., 2019; Kalmpourtzidou et al., 2020). Low affordability of fruit and vegetables is a critical constraint (Hirvonen et al., 2020; Miller et al., 2016), but low access and acceptance of vegetables are also important constraints. Low-income urban populations are particularly at risk of under-consuming fruit and vegetables (Frank et al., 2019). In Bangladesh, it has been estimated that 75% of urban and 92% of rural populations eat less than five daily servings of fruit and vegetables (Mustafa et al., 2021). That study found housewives to

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have a particular risk of low intake. Another study of young children (6–23 months) in Dhaka found that low fruit and vegetable consumption is the main dietary factor contributing to the poor growth performance of children (Parvin et al., 2022).

Food production in urban and peri-urban areas can increase availability and access to fresh fruit and vegetables while creating livelihood opportunities along the value chain (FAO & CIRAD, 2021; Petrikova et al., 2024). Initiatives promoting urban and peri-urban food production in home gardens have gained momentum globally, particularly after the COVID- 19 pandemic. In Bangladesh, urban rooftop gardening is well-established (Rahman et al., 2015; Safayet et al., 2017). The country's 8th Five-Year Plan identifies rooftop gardens and vertical farming as strategies to bolster urban food security.

The promotion of home gardens in rural areas has a proven impact on food and nutrition in Bangladesh (Baliki et al., 2019, 2022; Bushamuka et al., 2005; Schreinemachers et al., 2016; Waid et al., 2022) and other countries (Blakstad et al., 2022; Depenbusch et al., 2022; Issahaku et al., 2023; Olney et al., 2013; Osei et al., 2016; Pillai et al., 2016; Schreinemachers et al., 2015, 2020; Zimpita et al., 2015). Home garden interventions combine nutrition education with gardening training and provide garden inputs and tools to simultaneously raise household vegetable demand and supply. While there is strong evidence for the impact of rural home gardens, the evidence basis for urban home gardens remains weak, especially for lower-income countries.

Garcia et al. (2018) reviewed the impact of urban gardens on food and nutrition-related outcomes for studies published between 2005 and 2015. They found only twelve impact studies. Several reported improvements in fruit and vegetable intake and healthy food practices, but only one was for a lower-income country. Furthermore, the quality of that single study was rated as weak as it had no control group. Nordhagen et al. (2019) studied the impact of an urban intervention in Dakar, Senegal that provided households with inputs for poultry-raising, raised tables to grow vegetables, and nutrition training. They found that 18 months after the intervention, only 5% of participants continued growing vegetables, while 75% continued poultry-rearing, which was considered more lucrative.

While urban and rural gardens share the same principles, context and constraints differ. Rural gardens' positive impact cannot be generalized to urban gardens. Typical challenges to urban gardens include limited space, limited access to clean water, land insecurity and high land prices, soil and water pollution, and competing demands for people's time (Bennedetti et al., 2023; Olumba et al., 2021). Therefore, many development practitioners and policymakers are skeptical about the potential of urban to supply food. However, proponents point to the multiple benefits of urban gardening besides food production, such as greening cities, reconnecting people to food production, creating social cohesion in urban communities, shorter value chains with little postharvest losses, and employment creation (Alaimo et al., 2008; Beed et al., 2015; Orsini et al., 2013; Puigdueta et al., 2021). Gardening can also give people a sense of personal joy and accomplishment, which was particularly important during the COVID- 19 pandemic (Lal, 2020).

There is a need to understand the impact of urban gardening programs on lower-income countries to guide program design and urban food security strategies. This study's objective is to strengthen the basis of evidence through a rigorous impact evaluation of an urban gardening program in Dhaka, Bangladesh.

2 Methods

2.1 Intervention studied

The project "Support for Modelling, Planning and Improving Dhaka's Food System (DFS; 2019–2023)," funded by the government of the Netherlands, was used as a case study to test our hypothesis that urban garden interventions contribute to healthier diets and other benefits. The Food and Agriculture Organization of the United Nations and Wageningen University & Research implemented the DFS project. The project aimed to strengthen urban food system planning and governance, promote nutrition and food security and strengthen food value chains in partnership with the local government. The project piloted gardening with 400 households in 2021 before scaling it to 5,000 households during 2022 and 2023, targeting four city corporations (administrative subdivisions headed by a mayor) within the Dhaka Metropolitan Area: Dhaka North, Dhaka South, Gazipur, and Narayanganj.

The intervention was implemented by Proshika, a local non-governmental organization that supports low-income people through agriculture, health education, and other areas. The impact evaluation focused on households trained from January to April 2023. Proshika prepared a list of city wards and potential households, separated between rooftop gardens (2,000 households) and land-based gardens (5,000 households). City wards were randomly assigned to Control or Treatment. Households were selected by Proshika staff together with local community leaders. The project used a set of criteria to guide the household selection, but these were not strict exclusion criteria: (a) willingness to establish or get involved in urban gardening and having access to space for growing plants; (b) interest in converting an ornamental garden into a food-producing garden; (c) previous experience in vegetable gardening; (d) availability of labor for daily care and maintenance of the garden and willingness to do physical work in the garden; (e) access to a water source for garden irrigation; (f) willingness to properly use the supplied inputs and technical support; and (g) willing to receive visitors to the garden (e.g., project staff, governments officers). Program participants were identified as the person in charge of the garden if the households already had a garden, or the person most likely in charge of the garden if the household would establish one. Most project participants were women.

Training topics ranged from food safety and nutrition to water management, integrated pest management, growing media/soil preparation, potting/repotting, and vegetable/fruit growing techniques. Participants were given gardening tools, vegetable seeds, fruit tree saplings, and fertilizer. The intervention promoted rooftop and conventional surface-based gardens. The intervention used a training-of-trainers approach: master trainers were trained during a two-day session, who, in turn, taught other households and provided them with input and technical support.

The average household in the training group participated in 2.6 half-day training sessions. Table 1 lists aspects of the intervention as reported by program participants during the endline survey. It shows a high attendance of training sessions, particularly by women (85%), and it confirms that nearly all households received the complete package of input support. Of the participants, 97% were satisfied or highly satisfied with the support they had received.

The project's theory of change assumes that nutrition and technical training, combined with garden inputs and support, will allow urban households, primarily women, to establish a garden to produce modest quantities of fruits and vegetables or, if they already have a garden, to significantly increase productivity by addressing various gardening challenges. Households are expected to consume most of the garden produce within their household but may sell the surplus or share it with neighbors. The increased consumption of fruit and vegetables is expected to contribute to better quality diets. Gardening is, however, also expected to bring other benefits, such as creating a greener environment, strengthening urban communities' social cohesion, and enhancing people's life satisfaction.

Table 1 Aspects of the urban gardening intervention in Dhaka

Training aspects	Percentage of households
Participation in training sessions	100
Gender of participants:	
- Women	85
- Men	15
Input support received:	
- Vegetable seeds	99
- Fruit tree saplings	98
- Fertilizers	98
- Agricultural tools	99
Satisfaction with the support provided:	
- Satisfied/very satisfied	97
- Neutral	1
- Unsatisfied	1

Based on the sample of 425 households in the treatment group

2.2 Sampling and data collection

Optimal Design Plus was used to estimate the required sample size based on fruit and vegetable intake as the primary outcome of interest. We assumed an alpha value of 0.05 and a power (beta) of 80%. We determined that a sample of 800 households could detect a small to medium effect size (about 0.18) with 80% power.

The baseline survey was conducted from late August to early September 2022, and the endline was conducted one year later. The baseline included 1,326 households. We took a relatively large sample to do additional statistical analysis of urban food producers in Dhaka (reported elsewhere). Budget constraints forced us to reduce the sample size for the endline survey. We aimed for a sample of 700 households, but 21 households attrited from the sample (9 had moved, 3 were sick, 4 were absent, and 5 refused to participate). This sample is less than the original aim of 800 households and might cause some outcome variables with high variance to become insignificant.

The questionnaire was designed in English and translated into Bangla. It was tested on out-of-sample households in Dhaka and further refined. Male and female enumerators were trained for four days on the questionnaire and using digital tablets for the survey. ODK Collect was used to administer the interviews and manage the data. This study underwent an ethical review by the Institutional Biosafety and Research Ethics Committee (IBREC) of the World Vegetable Center and was approved (registration nr. 2022–016) on 5 August 2022. An information sheet on the nature of the survey and intervention was read to each respondent, and oral consent was required before the start of the interview.

2.3 Evaluation design

The study was designed as a cluster-randomized controlled trial (cRCT) in which the intervention was randomly assigned to groups of eligible households at the level of city wards. Randomization usually guarantees that the Treatment and Control groups are comparable in all aspects, with only program participation being different. Home garden interventions are suitable for applying such design because the population of eligible households is typically large (Depenbusch et al., 2021, 2022; Olney et al., 2016; Schreinemachers et al., 2020).

While the study was designed as a cRCT, it was realized during the endline data collection that gardening support had been provided to a substantial fraction of Control households while many Treatment households had not received support. Program placement was, therefore, no longer random. Households had to be reassigned between Control and Treatment. Consequently, this became a quasi-experimental study design using panel data for Control and Treatment groups collected before and after the intervention.

The intervention's impact is quantified using a difference-in-difference (DID) method. Impact is measured as the average treatment effect (ATE), defined as the change in outcomes for the treatment group minus the change in outcomes for the control group, using the following equation:

$$\text{Outcome} = \alpha + \beta(\text{Treatment}) + \gamma(\text{Period}) + \delta(\text{Treatment} \times \text{Period}) + \varepsilon_{\text{i}}) \tag{1}$$

where *Treatment* is a dummy variable separating the intervention group from the control group and *Period* is a dummy variable separating pre- and post-intervention data. The parameter δ represents the ATE. The model was estimated using ordinary least squares regression with robust standard errors for continuous outcomes and a logit regression with robust standard errors for binary outcomes. Odds ratios of the logit model were expressed as marginal effects for a switch from Control at baseline to Treatment at endline. We accounted for clustering at the ward level.

The DID design effectively deals with program placement bias. By comparing how the Treatment and Control groups change over time, any level differences between the two groups at the baseline are removed. Adding covariates to account for baseline differences is unnecessary and not advisable (Roth et al., 2023). The DID method's key assumption is that the average outcome for Treatment and Control would have followed "parallel trends" without the intervention. This assumption is likely to hold in our sample because treatment and comparison households come from the same cities and will be affected by similar trends such as weather, changes in input prices, or changes in retail prices of fruit and vegetables. Spillovers between Treatment and Control could be a more serious source of bias. However, spillover effects are unlikely to occur within one year; the intervention was assigned at the ward level, making spillovers less likely; and no Control households had received training or inputs. Spillover effects are, therefore, not a source of concern.

2.4 Outcomes measured

The study's primary outcome is fruit and vegetable consumption, but a more comprehensive range of outcomes was used to trace the intervention's impact pathway and to consider the multiple benefits of gardening. Outcome variables are categorized into food production, consumption, and other benefits, as described in the following.

2.4.1 Garden practices

Garden adoption (binary): A binary variable that indicates whether a household has a garden producing fruit or vegetables.

Garden size (m^2): The area used to produce fruit and vegetables measured in square feet and converted to square meters (m^2). The area was estimated by respondents, not measured by enumerators.

Garden practices (0–15): The number of good agricultural practices applied from a standard list of 15 practices (e.g., nurseries to raise seedlings, compost making, crop rotation, and mulching).

Species diversity (count): The number of different fruit and vegetable species grown during the most recent summer season (March-June), monsoon season (July–October), and winter season (November-February).

2.4.2 Production outcomes

Harvest frequency (count): The number of times households harvested fruit or vegetables from their garden during the most recently completed summer, monsoon, and winter seasons. The measure was expressed as the average number of harvests per week. The average harvest frequency per year was also calculated.

Selling fruit and vegetables (binary and USD/year): It was recorded whether a household sold fruit and vegetables in the past 12 months and the total earnings received in Bangladesh taka and converted to US dollars (USD).

Sharing fruit and vegetables (binary and frequency): It was recorded whether a household shared any garden produce with neighbors in the past 12 months and the number of times produce was shared (times/year).

2.4.3 Consumption outcomes

Food and nutrition knowledge (0–1): Measured using 12 statements that reflect the contents of the nutrition training. Half of the statements were factually correct (e.g., "Carrots, pumpkins, and orange sweet potatoes are sources of vitamin A"), and half were factually incorrect (e.g., "Pregnant women should avoid foods high in iron such as leafy vegetables"). The score is the proportion of correct answers.

Buying fruit and vegetables (USD/year): The money spent on buying fruit and vegetables from the market was recorded by asking the person in charge of food purchasing. The recall period was "a usual week." Answers were recorded in Bangladesh taka and converted to USD per year.

All other consumption outcomes were based on questions asked to a female household member and only referred to women. This was done so that the data would be more comparable between households and because women are more likely to do gardening.

Dietary diversity score (xDDS) (0–10): Diversity of food groups consumed from a list of 10 standard food groups, based on the Diet Quality Questionnaire (DQQ) for Bangladesh, which includes 27 binary questions about local foods using an individual 24-h recall (Global Diet Quality Project, 2021).

Minimum Dietary Diversity for Women (MDD-W) (binary): Calculated from the DQQ, it is achieved when five or more of the ten specific food groups are consumed by an individual over the course of a day. Women who do not meet the MDD-W are at higher risk of inadequate micronutrient intake.

All- 5 (binary): Calculated from the DQQ, it is achieved when all five recommended food groups are consumed, meaning at least one vegetable, one fruit, one pulse, nut or seed, one animal-source food, and at least one starchy staple.

Zero vegetable/fruit consumption (binary): Calculated from the DQQ, it takes the value of one if the woman consumed at least one vegetable over the course of a day and zero otherwise. The same measure is used for fruit.

Non-Communicable Disease (NCD)-Risk score (0–5): Calculated from the DQQ, it is a proxy for ultra-processed food intake. The Bangladesh DQQ lists five ultra-processed foods; hence, the score ranges from 0 to 5. A positive value would indicate an adverse effect of the intervention as respondents have increased their ultra-processed food intake.

Fruit and vegetable consumption (servings): Measured following Van Assema et al. (2002). The module is asked to the woman and refers to regular meals eaten during the last couple of weeks. It first asks how often she ate cooked vegetables a week (days/week). It then asks for a day that she ate vegetables how many meals usually included vegetables (meals/day). Finally, it asks, in a meal that included cooked vegetables, how many serving spoons she usually ate (servings/meal). The three variables are then multiplied to get the average number of portions of cooked vegetables/day. The method uses a local serving spoon that is shown physically and photos of portion sizes of different cooked vegetable dishes. The same questions are asked for raw vegetables, while only the first and last questions are asked for fruits.

Food Insecurity Experience Scale (FIES): The measure follows (Ballard et al., 2014; Cafiero et al., 2018). The questionnaire module consists of eight questions regarding people's access to adequate food using a 12-month recall. The individual-level version was used. The outcome has a raw score based on an ordinal scale and a Rasch score based on a logarithmic scale. One of the eight questions was dropped from the analysis as the outfit score was high, suggesting the question was poorly understood.

2.4.4 Other benefits and costs

Respondents were asked about other benefits they associated with gardening using a set of seven possible benefits, including: (a) eating more fruit or vegetables, (b) earning income, (c) enjoy growing plants, (d) the house looks better, (e) brings the family together, and (f) increases social interaction with neighbors. Possible answers were "not," "a little," and "a lot." The first two answers were coded as 0, the others as 1. The average level of agreement was calculated over the seven statements.

2.4.5 Other variables included

The survey recorded personal characteristics, including age, gender, and education level of the person in charge of the garden and their spouse. Also recorded were the characteristics of the house, such as whether it is a concrete single/multi-story concrete house or a tin shed house, and access to a water source. We recorded the type of garden (rooftop, soil surface-based) and problems encountered in gardening (e.g., lack of space, lack of water, etc.).

3 Results

3.1 Study sample characteristics

The average household in the sample has 4.7 members (Table 2). Women account for 82% of the study respondents. Fourteen percent of households are from informal settlements (slum areas). The average home is 93 m^2 in size. About half the sample homes are multi-story concrete houses, with single-story concrete and thin shed homes making up 13% and 34% of the sample, respectively. The share of tin shed homes is significantly larger in the Treatment than in the Control ($p = 0.002$). In 79% of the cases, the household owns the house. The total sample is equally spread over Dhaka's four city corporations, but the Control includes more households from Dhaka South and

Table 2 Mean socioeconomic and demographic characteristics of sampled households at baseline, in proportions unless indicated otherwise

	Control (n = 254)		Treatment (n = 425)		Total (n = 679)		p-value
	Mean	SD	Mean	SD	Mean	SD	
Household size (persons)	4.62	(1.78)	4.74	(1.99)	4.70	(1.91)	0.423
Female respondent	0.78		0.85		0.82		0.021
Respondent age (years)	41.63	(12.53)	39.88	(11.64)	40.53	(11.64)	0.058
Informal settlement	0.13		0.15		0.14		0.508
Dwelling size (m2)	97.55	(57.72)	90.02	(67.31)	92.84	(63.95)	0.138
Type of dwelling:							
- Multi-story concrete	0.59		0.43		0.49		< 0.001
- Single-story concrete	0.11		0.14		0.13		0.355
- Tin shed	0.27		0.39		0.34		0.002
Tenure situation:							
- Owned	0.77		0.81		0.79		0.252
- Rented	0.14		0.16		0.15		0.633
- No legal title	0.09		0.03		0.05		< 0.001
Location:							
- Dhaka North	0.24		0.25		0.25		0.823
- Dhaka South	0.37		0.25		0.30		0.001
- Gazipur	0.10		0.29		0.22		< 0.001
- Narayanganj	0.29		0.21		0.24		0.014
Household income (1,000 USD/month)	0.58	(0.61)	0.45	(0.51)	0.50	(0.55)	0.003
Own food production (past 12 months):							
- Animal products	0.30		0.40		0.36		0.005
- Edible plants	0.78		0.83		0.81		0.084
- Any food	0.82		0.87		0.85		0.061

* A Chi-squared significance test was conducted for categorical variables and a t-test of significance for continuous variables

Narayanganj, while the Treatment includes more households from Gazipur. The mean household income is USD 500 per month and is higher for the Control than the Treatment ($p = 0.003$). Finally, the data show that 85% of households at baseline engaged in urban food production (36% producing animal products and 81% producing edible plants), with the percentage slightly higher for the Treatment, but only at a 90% confidence interval.

In sum, the sample primarily represents households already involved in urban food production. The relatively low share of slum residents—14% in the sample but 37% of Dhaka residents (Streatfield & Karar, 2008)—and high ownership of homes suggest that the sample does not represent the poorest households in Dhaka. There are minor differences between the Treatment and Control groups.

Since most households are already engaged in urban gardening, it is worth looking at the main challenges they reported at the baseline (Fig. 1). The most prevalent obstacles in gardening were lack of knowledge and skills, insect pests and diseases, lack of inputs, shortage of soil, and animals destroying plants—each reported by at least 50% of gardeners. There are some notable variations. For instance, the shortage of soil was more of a challenge for rooftop gardeners and gardeners in slum areas. Insect pests and diseases and animals destroying plants were more common problems for those who gardened in surface soils rather than rooftops. Problems with polluted or poor-quality soils were reported by 33% of gardeners, and not having enough space affected 31%. Minor issues, reported by less than 10% of gardeners, included insufficient time, shading of gardens in buildup areas, lack of clean water, lack of household support, unreliable access to land, and seasonal flooding.

3.2 Impact on garden practices and food production

At the endline, all Treatment households had adopted gardening (Table 3). As adoption also increased in the Control group, the effect size was small (1% and insignificant ($p = 0.118$). There was no significant effect on the mean garden size ($p = 0.184$). However, the intervention did help gardeners adopt more good agricultural practices with a mean effect of 1.4 additional practices ($p < 0.001$).

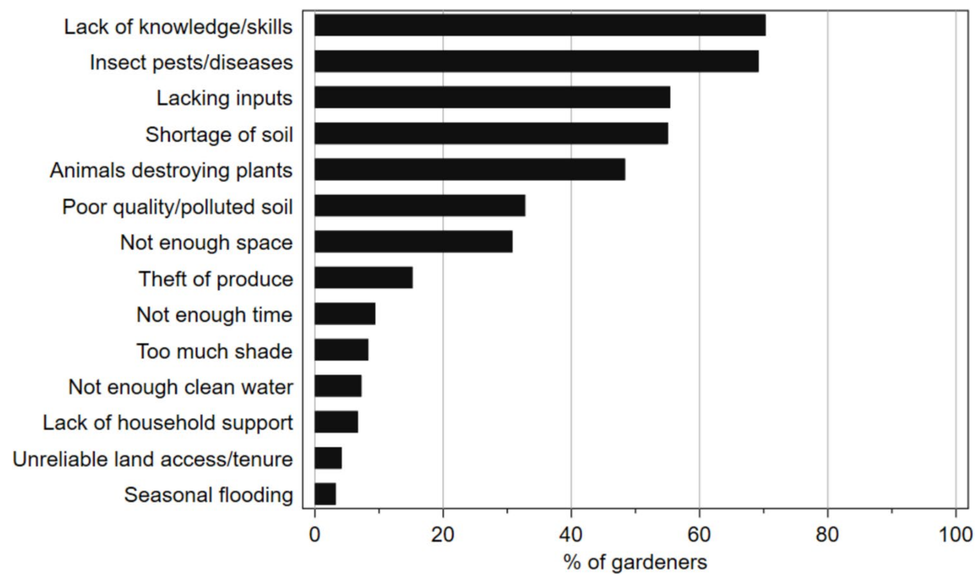


Fig. 1 Challenges to urban gardening as reported at baseline (n = 522)

The intervention resulted in an increase in the number of different species of vegetables (+ 2.4 species) and fruits (+ 2.6 species) grown in gardens, all effects being highly significant ($p < 0.001$). The frequency of harvesting garden produce increased by 0.6 times per week on average over the year ($p < 0.001$). Increased harvesting is observed for every season, but the effect size is the largest for the winter season. In the week before the endline survey, 85% of households in the Treatment had harvested produce from their garden, with the treatment effect being 14% ($p < 0.001$).

Of the households in the Treatment, 89% shared garden produce with neighbors, with the effect size being 8% ($p < 0.001$). Trained households shared their produce with neighbors on average 17 times a year, of which 5.2 times/year were attributable to the intervention ($p = 0.110$). Selling garden produce was uncommon, as only 14% of gardeners reported this at the endline. Nevertheless, the average household earned about USD 14 per year from selling produce. However, the intervention had no significant effect on selling garden produce.

3.3 Impact on food consumption

The training improved participants' nutritional knowledge by 4% ($p = 0.052$), as shown by the average treatment effect in Table 4. Regarding the 24-h diet quality indicators recorded for women, the dietary diversity score (0–10) increased by 0.37 ($p = 0.032$), and the Minimum Dietary Diversity for Women increased by 4% ($p = 0.008$). However, there was no significant effect on women's food group adequacy ($p = 0.347$) and the number of food groups consumed ($p = 0.261$), likely because nearly all women (95%) already eat vegetables daily. The intervention increased the consumption of ultra-processed foods associated with non-communicable diseases (NCD-Risk Foods) with a mean increase of 0.27 items per day ($p = 0.037$), a 19% increase and an adverse effect. The intervention positively affected household savings on fruit and vegetable purchases, with USD 107.5 spent less on buying fruit and vegetables per year ($p < 0.007$).

As women already ate cooked vegetables almost every day of the week (mean of 6.5 days/week at baseline), the scope for impact was small, and the effect on the frequency of vegetable consumption expressed in days/week was not significant. There is more scope for increasing the consumption of raw vegetables and fruits (both consumed 3.5 days/week at baseline), but the intervention only affected the frequency of fruit consumption (+ 0.48 days/week; $p = 0.028$). However, women did eat additional portions of cooked vegetables (+ 0.86 portions; $p < 0.001$) and raw vegetables (+ 0.21 portions; $p = 0.095$), while there was no significant effect on the number of fruit portions ($p = 0.375$).

Finally, the average household was already relatively food secure at the baseline, with the average FIES being 1.38 on a 7-point scale (a higher score means more food insecure). Still, the intervention enhances food security, as shown by a 0.31 drop in food insecurity (ordinal scale; $p = 0.088$) but no significant effect on the logarithmic scale.

3.4 Other perceived benefits of gardening

Gardening was perceived to contribute to the enhancement of fruit and vegetable consumption by both the Control and Treatment groups, with close to 100% of gardening respondents affirming this (Fig. 2). Income benefits were only perceived as significant by about a quarter

Table 3 Gardening production characteristics at baseline, endline and estimated impact

Outcomes	Baseline			Endline			Impact [a]	
	C	T	p-value	C	T	p-value	ATE	p-value
Has a garden (0/1)	0.78	0.83	0.084	0.95	1.00	< 0.001	< 0.01	0.118
Garden size (m^2) [b]	71.10	79.16	0.259	79.13	113.88	0.136	26.69	0.184
	(69.00)	(86.19)		(131.75)	(348.10)			
Good garden practices applied (0–15) [b]	5.49	6.18	0.001	5.30	7.33	< 0.001	1.35	< 0.001
	(2.45)	(2.33)		(2.76)	(2.98)			
Species diversity, all seasons (number):								
- Vegetables	6.70	8.49	< 0.001	11.71	16.15	< 0.001	2.64	< 0.001
	(5.98)	(6.15)		(7.11)	(6.68)			
- Fruits	3.46	3.65	0.461	5.44	8.01	< 0.001	2.38	< 0.001
	(3.67)	(3.19)		(3.99)	(3.36)			
- Vegetables and fruits	10.15	12.15	0.004	17.15	24.16	< 0.001	5.02	< 0.001
	(9.14)	(8.61)		(10.11)	(9.14)			
Harvested frequency (days/week) [b]:								
- Summer (Mar-Jun)	1.87	1.99	0.285	1.67	2.26	< 0.001	0.47	0.003
	(1.27)	(1.24)		(1.36)	(1.46)			
- Monsoon (Jul-Oct)	1.99	2.05	0.639	1.42	2.04	< 0.001	0.55	0.002
	(1.61)	(1.53)		(1.36)	(1.52)			
- Winter (Nov-Feb)	2.18	2.31	0.327	2.12	3.19	< 0.001	0.94	< 0.001
	(1.49)	(1.45)		(1.62)	(1.91)			
- All seasons	2.01	2.12	0.371	1.73	2.47	< 0.001	0.64	< 0.001
	(1.33)	(1.29)		(1.31)	(1.43)			
Harvested from garden in past 7 days (0/1)	0.51	0.62	0.004	0.54	0.85	< 0.001	0.14	< 0.001
Sharing garden produce (0/1)	0.67	0.74	0.062	0.71	0.89	< 0.001	0.08	< 0.001
Sharing garden produce (times/year)	9.67	10.50	0.373	10.92	17.00	0.100	5.24	0.110
	(12.76)	(11.21)		(25.62)	(55.34)			
Selling garden produce (0/1)	0.06	0.12	0.007	0.07	0.17	< 0.001	0.02	0.757
Selling garden produce (times/year)	1.36	3.03	0.057	1.52	4.20	0.057	1.02	0.478
	(6.78)	(12.89)		(10.70)	(20.84)			
Selling garden produce (USD/year)	2.79	7.35	0.017	5.08	22.20	0.175	12.55	0.210
	(15.01)	(28.01)		(31.35)	(199.12)			

[a]Impact for continuous outcomes estimated using ordinary least squares regression. Impact for binary outcomes estimated using a logit regression and showing marginal effects expressed as a percentage change for the Treatment at the endline. [b] Estimated for the subpopulation of gardeners. Standard deviations in brackets. ATE = Average treatment effect. C = Control. T = Treatment

of the gardener population. All other benefits were recognized by the great majority of gardeners, including the enjoyment of growing plants, making the house look better, bringing the family together, and having more social interaction with neighbors. The results also show distinct psychological benefits, including a heightened sense of personal achievement, personal peace, and self-worth. For all these perceived benefits, the score for the Treatment is slightly higher than that for the Control. The DID estimator also confirms this, with the ATE being 0.44 ($p = 0.006$), meaning the gardeners achieved at least 0.44 additional benefits from the training (not shown).

4 Discussion

This study showed that providing gardening and nutrition training and inputs to urban households in metropolitan Dhaka helped participants establish a more productive garden with a greater diversity of fruits and vegetables, more use of good agricultural practices, and more frequent harvesting of fruit and vegetables, which were consumed by households and shared with neighbors. The study tested 38 outcome variables, of which 20 were significant at a 95% confidence interval (another four were significant at a 90% confidence interval). All but one of these outcomes were beneficial effects.

Table 4 Food and nutrition-related outcomes at baseline, endline and estimated impact

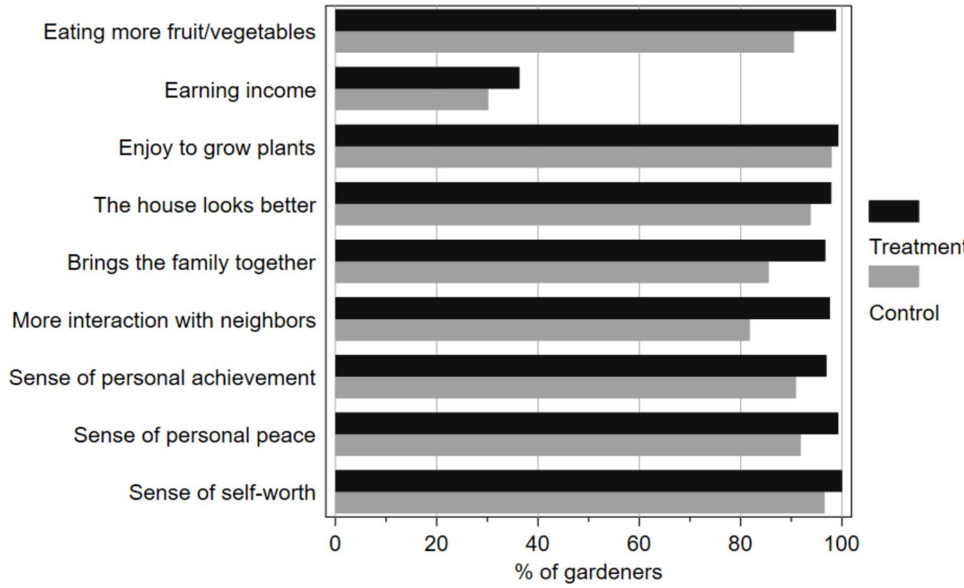
Outcomes	Baseline			Endline			Impact	
	C	T	p-value	C	T	p-value	ATE	p-value
Nutrition knowledge score (0–1)	0.76	0.76	0.568	0.78	0.82	< 0.001	0.04	0.052
	(0.20)	(0.17)		(0.15)	(0.11)			
Expenditure on fruits and vegetables (USD/year)	570.80	504.83	0.007	759.83	586.36	< 0.001	− 107.51	0.007
	(308.72)	(309.25)		(429.02)	(339.52)			
Diet quality indicators (24-h):								
- Dietary diversity score (0–10)	5.83	5.89	0.673	6.31	6.74	0.673	0.37	0.032
	(1.54)	(1.58)		(1.53)	(1.51)			
- Minimum Dietary Diversity (0/1)	0.81	0.81	0.999	0.87	0.94	0.999	0.04	0.008
- Food group adequacy (0/1)	0.52	0.55	0.496	0.70	0.76	0.496	0.04	0.347
- Number of food groups consumed (0–5)	4.40	4.40	0.979	4.61	4.70	0.979	0.09	0.261
	(0.71)	(0.76)		(0.65)	(0.60)			
- Consuming at least one vegetable (0/1)	0.89	0.92	0.349	0.93	0.96	0.349	0.01	0.371
- Consuming at least one fruit (0/1)	0.75	0.77	0.606	0.85	0.89	0.606	0.03	0.317
- NCD-Risk score (0–5)	1.34	1.42	0.375	1.48	1.82	0.375	0.27	0.037
	(1.04)	(1.21)		(1.15)	(1.2)			
F&V consumption (days/week):								
- Vegetables, cooked	6.58	6.53	0.526	6.40	6.49	0.526	0.14	0.225
	(0.94)	(0.98)		(1.15)	(1.09)			
- Vegetables, raw	3.46	3.46	0.989	3.06	3.18	0.989	0.11	0.590
	(2.00)	(1.93)		(1.83)	(1.71)			
- Fruits	3.80	3.24	< 0.001	3.83	3.75	< 0.001	0.48	0.028
	(2.10)	(1.89)		(1.92)	(1.86)			
F&V consumption (portions/day):								
- Vegetables, cooked	5.18	5.39	0.301	4.11	5.18	0.301	0.86	0.001
	(2.52)	(2.57)		(1.76)	(2.65)			
- Vegetables, raw	0.98	0.92	0.499	0.97	1.12	0.499	0.21	0.095
	(1.07)	(1.11)		(1.18)	(1.11)			
- Fruits	0.66	0.54	0.001	0.81	0.75	0.001	0.06	0.375
	(0.52)	(0.44)		(0.70)	(0.59)			
Food insecurity experience scale:								
- FIES, ordinal (0–7)	1.04	1.58	< 0.001	0.72	0.95	< 0.001	− 0.31	0.088
	(1.71)	(1.90)		(1.37)	(1.68)			
- FIES, interval (log)	− 0.89	− 0.66	< 0.001	− 1.03	− 0.93	< 0.001	− 0.13	0.110
	(0.75)	(0.84)		(0.58)	(0.73)			

[a]Impact for continuous outcomes estimated using ordinary least squares regression. Impact for binary outcomes estimated using a logit regression and showing marginal effects expressed as a percentage change for the Treatment at the endline. [b] Estimated for the subpopulation of gardeners. Standard deviations in brackets. ATE = Average treatment effect. C = Control, T = Treatment

Women increased their dietary diversity score directly through increased garden production, but there may also be an indirect effect through increased interest in healthy eating. This is confirmed by the intervention's positive effect on fruit consumption (fruit was consumed more days per week) because it is not realistic that households could have produced more fruit within 6–9 months of the training as most trees will require longer to start bearing fruit. The data confirm that the intervention had a greater impact on vegetable than fruit consumption. While most women already ate cooked vegetables daily, the daily portion size of cooked vegetables increased substantially.

Households considerably reduced fruit and vegetable purchases from the market, saving 108 USD per year on average. Nevertheless, fruit and vegetable consumption increased, showing that increased garden production more than offset reduced buying and even enabled more sharing with neighbors. However, some saved expenditures were likely spent on

Fig. 2 Perceived benefits of gardening at endline (n = 424)



ultra-processed foods, representing an adverse effect. The consumption of ultra-processed foods increased by 0.27 servings or 19% over the baseline. This effect is substantial. The overall consumption of ultra-processed foods may still be low compared to some high-income countries, where these foods account for about half of adults' energy intake (e.g. Martínez Steele et al., 2017; Nardocci et al., 2019). Nevertheless, it is advisable to address the health risks of ultra-processed food consumption through the intervention's nutrition training component.

There may be other adverse effects that were not measured in this study. For instance, the production of vegetables with soil or water contaminated with heavy metals or pathogens can pose a human health risk, as shown by several studies that analyzed fruit and vegetable samples in Dhaka markets (Ahmad & Goni, 2010; Ahmed et al., 2019; Pramanik et al., 2025; Shaheen et al., 2016; Sultana et al., 2022). It may be that urban produced vegetables have a higher risk of contamination with heavy metals and pathogens than those coming from rural areas, but we are not aware of any studies that compared these. On the other hand, vegetables produced in urban home gardens may pose a lower contamination risk for pesticide residues and chemical preservatives, which are also common food safety challenges in Dhaka (Ahmed et al., 2019; Haque et al., 2024). An analysis of these aspects was outside the scope of this study but is worth looking into.

4.1 Strengths and limitations of the study

This study is unique in its broad scope of outcome variables covering production, consumption, and other less material benefits. No previous study of home gardens has used such a comprehensive set of outcome variables. It allows for tracing the impact of an increase in knowledge to improvements in production practices, eventually leading to improved nutrition. It is also one of the first rigorous impact evaluations of home garden interventions in an urban context.

A weakness of the study is that randomization of training support over households in the sample was not achieved. Another weakness is that study participants are not representative of Dhaka's poor—slum dwellers appear to be underrepresented, while homeowners with rooftops appear overrepresented. It would not have been easy to correct this because project participation was voluntary, and people already involved in food production have a keener interest than people without any experience in food production or without any resources like access to space. It is also unclear if the sample bias creates a negative or positive outcome bias: households already involved in food production may be more eager to adopt innovations, but the scope for impact would have been greater for households not already producing food.

Another weakness was the short, one-year period between baseline and endline. The study shows evidence for the immediate impact of the intervention, but not for its sustainability. A follow-up study is recommended.

Furthermore, there was an apparent increase in the adoption of home gardens and the use of species diversity from baseline to endline for both the Treatment and the Control. This may suggest that some of the effects of the intervention spilled over to the Control. While we cannot rule this out entirely, we think spillover effects are minimal because entire wards were assigned to Treatment or Control. The average ward size in Dhaka North and Dhaka South is about 2.3 km^2 and 78,000 people per ward. Therefore, it is unlikely that Control and Treatment households would meet. However, being included in the study may have incentivized Control households to adopt a garden.

4.2 Implications for policy and development

Gardening support programs are common in Bangladesh and elsewhere. The evidence suggests that such programs help rural households to produce and consume more vegetables (Baliki et al., 2022; Blakstad et al., 2021; Depenbusch et al., 2022). The evidence is particularly strong for Bangladesh, but all previous studies focused on the rural context (Baliki et al., 2019; Bushamuka et al., 2005; Marsh & Talukder, 1994; Schreinemachers et al., 2016). This study shows that a similar impact is also observed in the urban context. This is good news because gardening programs are relatively straightforward to implement by non-governmental organizations, and impacts are observable after a short time (6–9 months in this study).

Two questions often raised concerning home gardens are their scaleability and sustainability. While urban gardening is common in cities like Dhaka, many gardens are rather unproductive. Scaling the benefits of urban gardening requires external support, including training and some input provision. In their review of urban horticulture, Eigenbrod and Gruda (2015) wrote that for sustainability, urban horticulture must be integrated into urban planning and supported through policies. This also applies to Dhaka. Fortunately, city and national governments already recognize the importance of urban food production to food security. Impact studies like these may help them justify allocating resources to support urban food producers.

The home garden literature is unclear about the sustainability of home garden interventions, partly because only a few studies have analyzed it. A study in Tanzania showed a positive impact on dietary diversity after one year, but the impact had disappeared after three years (Blakstad et al., 2022). A study in rural Bangladesh compared effects after one, three, and six years and showed that the impact on production was sustained for six years, but the impact on vegetable intake was only sustained for three years (Baliki et al., 2022). Finally, a study of microgarden tables in Dakar, Senegal—one of few impact studies of urban agriculture in a low-income country—showed that only 5% of households continued to use their tables to grow vegetables 18 months after the project (Nordhagen et al., 2019). The Bangladesh study is probably the most comparable to our intervention and suggests that the impact of garden interventions is sustained for several years, but refresher training is needed after 3–5 years.

City governments can support urban gardening by recognizing its importance in local food security strategies and allocating resources to support gardeners. Lack of space and water, seasonal flooding, or uncertain tenure rights—all of which are regularly mentioned as unsurmountable constraints to urban food production, were not mentioned as significant hurdles by urban gardeners interviewed for this study. The main constraints were the lack of knowledge and skills, control of insect pests and diseases, lack of inputs, and lack of access to good soil—each of which can be addressed through extension support.

5 Conclusion

An intervention providing urban residents in the Dhaka metropolitan area with training in gardening and nutrition and some gardening inputs significantly improved the quality of women's diets and brought various other social, personal, and psychological benefits. Dhaka is very suitable for urban gardening because rooftops are usually flat and accessible, and many people are familiar with gardening. This study showed that a relatively straightforward promotion of urban gardening and nutrition brings substantial benefits. Supporting urban households and food producers with extension services may be worthwhile to further scale the benefits of urban gardening and strengthen the resilience of urban food systems.

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Data Availability The data are available from the authors on request.

Declarations

Competing interests The first author is Associate Editor for this journal.

References

Ahmad, J. U., & Goni, M. A. (2010). Heavy metal contamination in water, soil, and vegetables of the industrial areas in Dhaka. *Bangladesh. Environmental Monitoring and Assessment, 166*(1), 347–357.

Ahmed, S., Siddique, M. A., Rahman, M., Bari, M. L. & Ferdousi, S. (2019). A study on the prevalence of heavy metals, pesticides, and microbial contaminants and antibiotics resistance pathogens in raw salad vegetables sold in Dhaka, Bangladesh. *Heliyon 5*(2).

Alaimo, K., Packnett, E., Miles, R. A., & Kruger, D. J. (2008). Fruit and vegetable intake among urban community gardeners. *Journal of Nutrition Education and Behavior, 40*(2), 94–101.

Ameye, H. (2023). Dietary quality in rural areas, secondary towns, and cities: Insights from Tanzania. *Food Security, 15*(6), 1563–1584.

Baliki, G., Brück, T., Schreinemachers, P., & Uddin, M. N. (2019). Long-term behavioural impact of an integrated home garden intervention: Evidence from Bangladesh. *Food Security, 11*, 1217–1230.

Baliki, G., Schreinemachers, P., Brück, T., & Uddin, N. M. (2022). Impacts of a home garden intervention in Bangladesh after one, three and six years. *Agriculture & Food Security, 11*(1), 48.

Ballard, T., Kepple, A., Cafiero, C., & Schmidhuber, J. (2014). Better measurement of food insecurity in the context of enhancing nutrition. *Ernahrungs Umschau, 61*(2), 38–41.

Beed, F., Dubois, T. & Yang, R. (2015). Nutrition implications of urban and peri-urban agriculture. *Agriculture for Development* (No.26): 7–11.

Bennedetti, L. V., de Almeida Sinisgalli, P. A., Ferreira, M. L., & Lemes de Oliveira, F. (2023). Challenges to Promote Sustainability in Urban Agriculture Models: A Review. *International Journal of Environmental Research and Public Health, 20*(3), 2110.

Blakstad, M. M., Mosha, D., Bellows, A. L., Canavan, C. R., Chen, J. T., Mlalama, K., Noor, R. A., Kinabo, J., Masanja, H., & Fawzi, W. W. (2021). Home gardening improves dietary diversity, a cluster-randomized controlled trial among Tanzanian women. *Maternal & Child Nutrition, 17*(2), e13096.

Blakstad, M. M., Mosha, D., Bliznashka, L., Bellows, A. L., Canavan, C. R., Yussuf, M. H., Mlalama, K., Madzorera, I., Chen, J. T., Noor, R. A., Kinabo, J., Masanja, H., & Fawzi, W. W. (2022). Are home gardening programs a sustainable way to improve nutrition? Lessons from a cluster-randomized controlled trial in Rufiji. *Tanzania. Food Policy, 109*, 102248.

Bushamuka, V. N., de Pee, S., Talukder, A., Kiess, L., Panagides, D., Taher, A., & Bloem, M. (2005). Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh. *Food and Nutrition Bulletin, 26*(1), 17–25.

Cafiero, C., Viviani, S., & Nord, M. (2018). Food security measurement in a global context: The food insecurity experience scale. *Measurement, 116*, 146–152.

Depenbusch, L., Schreinemachers, P., Roothaert, R., Namazzi, S., Onyango, C., Bongole, S., & Mutebi, J. (2021). Impact of home garden interventions in East Africa: Results of three randomized controlled trials. *Food Policy, 104*, 102140.

Depenbusch, L., Schreinemachers, P., Brown, S., & Roothaert, R. (2022). Impact and distributional effects of a home garden and nutrition intervention in Cambodia. *Food Security, 14*(4), 865–881.

Eigenbrod, C., & Gruda, N. (2015). Urban vegetable for food security in cities. *A Review. Agronomy for Sustainable Development, 35*(2), 483–498.

FAO & CIRAD. (2021). *Fruit and vegetables – Opportunities and challenges for small-scale sustainable farming*. Food and Agriculture Organization of the United Nations.

Frank, S. M., Webster, J., McKenzie, B., Geldsetzer, P., Manne-Goehler, J., Andall-Brereton, G., Houehanou, C., Houinato, D., Gurung, M. S., Bicaba, B. W., McClure, R. W., Supiyev, A., Zhumadilov, Z., Stokes, A., Labadarios, D., Sibai, A. M., Norov, B., Aryal, K. K., Karki, K. B., … Jaacks, L. M. (2019). Consumption of Fruits and Vegetables Among Individuals 15 Years and Older in 28 Low- and Middle-Income Countries. *The Journal of Nutrition, 149*(7), 1252–1259.

Garcia, M. T., Ribeiro, S. M., Germani, A. C. C. G., & Bógus, C. M. (2018). The impact of urban gardens on adequate and healthy food: A systematic review. *Public Health Nutrition, 21*(2), 416–425.

Global Diet Quality Project (2021). DQQ for Banglades. Accessed at https://www.dietquality.org/.

Haque, M. L., Oosterveer, P., & Vignola, R. (2024). Food safety concerns and purchase choices among poor households in the urbanising global south: The case of Dhaka. *Bangladesh. Food Security, 16*(4), 933–950.

Hirvonen, K., Bai, Y., Headey, D., & Masters, W. A. (2020). Affordability of the EAT-Lancet reference diet: A global analysis. *The Lancet Global Health, 8*(1), e59–e66.

HLPE. (2024). *Strengthening urban and peri-urban food systems to achieve food security and nutrition, in the context of urbanization and rural transformation*. CFS HLPE-FSN.

Issahaku, G., Kornher, L., Saiful Islam, A. H. M., & Abdul-Rahaman, A. (2023). Heterogeneous impacts of home-gardening on household food and nutrition security in Rwanda. *Food Security, 15*(3), 731–750.

Kalmpourtzidou, A., Eilander, A., & Talsma, E. F. (2020). Global Vegetable Intake and Supply Compared to Recommendations: A Systematic Review. *Nutrients, 12*(6), 1558.

Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. *Food Security, 12*(4), 871–876.

Marsh, R. R. & Talukder, A. (1994). Effects of the introduction of home gardening on the production and consumption of target, interaction, and control groups: a case study from Bangladesh. In *Systems-Oriented Research in Agriculture and Rural Development,International Symposium* 425–430 Montpellier, France 21–24

Martínez Steele, E., Popkin, B. M., Swinburn, B., & Monteiro, C. A. (2017). The share of ultra-processed foods and the overall nutritional quality of diets in the US: Evidence from a nationally representative cross-sectional study. *Popul Health Metr, 15*(1), 6.

Miller, V., Yusuf, S., Chow, C. K., Dehghan, M., Corsi, D. J., Lock, K., Popkin, B., Rangarajan, S., Khatib, R., Lear, S. A., Mony, P., Kaur, M., Mohan, V., Vijayakumar, K., Gupta, R., Kruger, A., Tsolekile, L., Mohammadifard, N., Rahman, O., … Mente, A. (2016). Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: Findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet Global Health, 4*(10), e695–e703.

Mustafa, S., Haque, C. E., & Baksi, S. (2021). Low Daily Intake of Fruits and Vegetables in Rural and Urban Bangladesh: Influence of Socioeconomic and Demographic Factors, Social Food Beliefs and Behavioural Practices. *Nutrients, 13*(8), 2808.

Nardocci, M., Leclerc, B. S., Louzada, M. L., Monteiro, C. A., Batal, M., & Moubarac, J. C. (2019). Consumption of ultra-processed foods and obesity in Canada. *Canadian Journal of Public Health, 110*(1), 4–14.

Nordhagen, S., Thiam, K., & Sow, S. (2019). The sustainability of a nutrition-sensitive agriculture intervention: A case study from urban Senegal. *Food Security, 11*(5), 1121–1134.

Olney, D. K., Vicheka, S., Kro, M., Chakriya, C., Kroeun, H., Hoing, L. S., Talukder, A., Quinn, V., Iannotti, L., Becker, E., & Roopnaraine, T. (2013). Using program impact pathways to understand and improve program delivery, utilization, and potential for impact of Helen Keller International's Homestead Food Production Program in Cambodia. *Food and Nutrition Bulletin, 34*(2), 169–184.

Olney, D. K., Bliznashka, L., Pedehombga, A., Dillon, A., Ruel, M. T., & Heckert, J. (2016). A 2-Year Integrated Agriculture and Nutrition Program Targeted to Mothers of Young Children in Burkina Faso Reduces Underweight among Mothers and Increases Their Empowerment: A Cluster-Randomized Controlled Trial. *The Journal of Nutrition, 146*(5), 1109–1117.

Olumba, C. C., Olumba, C. N., & Alimba, J. O. (2021). Constraints to urban agriculture in southeast Nigeria. *Humanities and Social Sciences Communications, 8*(1), 329.

Orsini, F., Kahane, R., Nono-Womdim, R., & Gianquinto, G. (2013). Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development, 33*(4), 695–720.

Osei, A., Pandey, P., Nielsen, J., Pries, A., Spiro, D., Davis, D., Quinn, V., & Haselow, N. (2016). Combining Home Garden, Poultry, and Nutrition Education Program Targeted to Families With Young Children Improved Anemia Among Children and Anemia and Underweight Among Nonpregnant Women in Nepal. *Food and Nutrition Bulletin, 38*(1), 49–64.

Parvin, T., Endres, K., Hasan, M. T., Uddin, I. M., Bhuyian, M. S. I., Zohura, F., Coglianese, N., Biswas, S. K., Alam, M., Faruque, A. S. G., Gittelsohn, J., Perin, J., & George, C. M. (2022). Low Fruit and Vegetable Consumption Associated with Linear Growth Faltering among Children in Urban Bangladesh. *American Journal of Tropical Medicine and Hygiene, 106*(6), 1741–1746.

Petrikova, I., Otieno, M. A., Were, G., Eltholth, M., Mateos, A. R., Harding, S., Moran, V., Osano, O. & Cole, J. (2024). Peri-urban agriculture and household food and nutrition security around Eldoret, Kenya. *Food Security, 16,* 1235–1263.

Pillai, A., Kinabo, J., & Krawinkel, M. B. (2016). Effect of nutrition education on the knowledge scores of urban households with home gardens in Morogoro. *Tanzania. Agriculture & Food Security, 5*(1), 22.

Popkin, B. M. (2014). Nutrition, agriculture and the global food system in low and middle income countries. *Food Policy, 47*, 91–96.

Pramanik, P. K., Hoque, M. N., Rana, M. L., Islam, M. S., Ullah, M. A., Neloy, F. H., Ramasamy, S., Schreinemachers, P., Oliva, R. & Rahman, M. T. (2025). Prevalence and antibiotic resistance of Escherichia coli in urban and peri-urban garden ecosystems in Bangladesh. *PLoS One 20*(2), e0315938.

Puigdueta, I., Aguilera, E., Cruz, J. L., Iglesias, A., & Sanz-Cobena, A. (2021). Urban agriculture may change food consumption towards low carbon diets. *Global Food Security, 28*, 100507.

Rahman, A., Nabi, A. K. M., Mirza, M., Rahman, H., Hossain, M., Syed, M., Amin, M., Hossain, P., Mamnun, N. & Rahman, S. (2015). *Building Urban Resilience - Assessing Urban and Peri-urban Agriculture in Dhaka, Bangladesh.* Nairobi, Kenya: United Nations Environment Programme (UNEP).

Roth, J., Sant'Anna, P. H. C., Bilinski, A. & Poe, J. (2023). What's trending in difference-in-differences? A synthesis of the recent econometrics literature. *Journal of Econometrics* 235(2): 2218-2244

Safayet, M., Arefin, M. F., & Hasan, M. M. U. (2017). Present practice and future prospect of rooftop farming in Dhaka city: A step towards urban sustainability. *Journal of Urban Management, 6*(2), 56–65.

Schreinemachers, P., Patalagsa, M. A., Islam, M. R., Uddin, M. N., Ahmad, S., Biswas, S. C., Ahmed, M. T., Yang, R.-Y., Hanson, P., Begum, S., & Takagi, C. (2015). The effect of women's home gardens on vegetable production and consumption in Bangladesh. *Food Security, 7*(1), 97–107.

Schreinemachers, P., Patalagsa, M. A., & Uddin, N. (2016). Impact and cost-effectiveness of women's training in home gardening and nutrition in Bangladesh. *Journal of Development Effectiveness, 8*(4), 473–488.

Schreinemachers, P., Baliki, G., Shrestha, R. M., Bhattarai, D. R., Gautam, I. P., Ghimire, P. L., Subedi, B. P., & Brück, T. (2020). Nudging children toward healthier food choices: An experiment combining school and home gardens. *Global Food Security, 26*, 100454.

Shaheen, N., Irfan, N. M., Khan, I. N., Islam, S., Islam, M. S., & Ahmed, M. K. (2016). Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh. *Chemosphere, 152*, 431–438.

Streatfield, P. K., & Karar, Z. A. (2008). Population challenges for Bangladesh in the coming decades. *Journal of Health, Population, and Nutrition, 26*(3), 261–272.

Sultana, R., Tanvir, R. U., Hussain, K. A., Chamon, A. S., & Mondol, M. N. (2022). Heavy Metals in Commonly Consumed Root and Leafy Vegetables in Dhaka City, Bangladesh, and Assessment of Associated Public Health Risks. *Environmental Systems Research, 11*(1), 15.

Tuholske, C., Andam, K., Blekking, J., Evans, T., & Caylor, K. (2020). Comparing measures of urban food security in Accra. *Ghana. Food Security, 12*(2), 417–431.

UN (2018). *World Urbanization Prospects: The 2018 Revision, Online Edition. Available at:* https://population.un.org/wup/Download/. United Nations, Department of Economic and Social Affairs, Population Division.

Van Assema, P., Brug, J., Ronda, G., Steenhuis, I., & Oenema, A. (2002). A Short Dutch Questionnaire to Measure Fruit and Vegetable Intake: Relative Validity Among Adults and Adolescents. *Nutrition and Health, 16*(2), 85–106.

Waid, J. L., Wendt, A. S., Sinharoy, S. S., Kader, A., & Gabrysch, S. (2022). Impact of a homestead food production program on women's empowerment: Pro-WEAI results from the FAARM trial in Bangladesh. *World Development, 158*, 106001.

WHO & FAO (2003). Diet, nutrition and the prevention of chronic diseases. Report of a Joint FAO/WHO Expert Consultation. *WHO Technical Report Series 916*. Geneva: World Health Organization.

Zimpita, T., Biggs, C., & Faber, M. (2015). Gardening practices in a rural village in South Africa 10 years after completion of a home garden project. *Food and Nutrition Bulletin, 36*, 33–42.

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