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ORIGINAL ARTICLE

Home gardens, household nutrition and income in rural farm households in Odisha, India

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Abstract

Home gardens have been an integral part of the recent food-based interventions aimed at stimulating changes in dietary patterns and improving nutrition. However, evidence of their effects on food security, dietary quality, child anthropometry and incomes is limited, particularly among vulnerable populations groups. Using panel data from a sample of approximately 1900 households from vulnerable population groups in Odisha, India, difference-in-differences and other econometric techniques, we analyse the effects of home gardens on food security, dietary quality, child anthropometry and income. On average, home gardens contribute to better household food security, higher dietary quality of men and women but do not contribute to higher children's dietary quality and anthropometry. Also, home gardens increase monthly per adult equivalent incomes by 37% and reduce the prevalence of poverty by 11.7 percentage points. Quantile regression results suggest that home gardens enhance food security and incomes in all quantiles, but richer farmers benefit more than poorer farmers. Overall, home gardens can enhance household food security, dietary quality of men and women, and income gains among vulnerable farming population groups, but they may not suffice to improve child dietary quality and anthropometry.

KEYWORDS

child anthropometry, dietary quality, food security, home gardens, India, smallholders

JEL CLASSIFICATION

I31, Q12, Q13, Q18

1 | INTRODUCTION

Hunger and malnutrition are widespread across the globe. An estimated 720–811 million people in the world are chronically undernourished and more than 2 billion are micronutrient deficient (FAO, 2021). Most of the people affected are in Asia and Africa, and mainly include rural farm households that rely on agriculture as their main source of food, employment and income (FAO, 2021; Pandey et al., 2016). Hunger and malnutrition have serious public health implications and contribute to the increased prevalence of stunting and wasting in children, nutrition-related diseases, disabilities and deaths (FAO, 2021; GNR, 2021). Against this background, recent policy focus has been on how to increase the nutritional impact of investments or interventions in the agricultural sector (Ruel et al., 2018; Sharma et al., 2021).

Promotion of nutrient-dense foods such as fruits, vegetables and pulses through home gardens coupled with animal production, aquaculture and behaviour change communication have been part of the recent food-based interventions aimed at stimulating changes in dietary patterns and improving nutrition (Fiorella et al., 2016; Osei et al., 2017). Recent studies have acknowledged that farm diversification in general and home gardens in particular can play an important role in improving nutritional outcomes (Bird et al., 2019; Castañeda-Navarrete, 2021).[1] The mechanism through which home gardens is expected to improve nutritional outcomes is simple. Households receive agronomic training on how to cultivate nutrient-rich crops (typically fruits and vegetables) year-round on small plots of land near their homesteads. They also receive nutrition training to increase their knowledge of nutrition and demand for home-produced nutrient-rich foods. Upon completion of the training, households are expected to establish home gardens with start-up support and optimally use available inputs to produce nutritious foods for household consumption (Schreinemachers et al., 2016).

Previous studies have examined the effects of home gardens on smallholders' household-level nutritional outcomes (Baliki et al., 2019; Castañeda-Navarrete, 2021; Depenbusch et al., 2021, 2022; Schreinemachers et al., 2016; Tesfamariam et al., 2018). The studies mostly show that home garden interventions increase the quantity and diversity of produced and consumed food at the household level. Other studies have explored the relationship between home garden interventions—sometimes combined with animal production (e.g., poultry or aquaculture)—on individual-level nutritional outcomes, such as child anthropometry (Murty et al., 2016; Olney et al., 2015; Osei et al., 2017) and dietary quality (Blakstad et al., 2021, 2022; Olney et al., 2015). However, concrete evidence of the impact of home gardens on child anthropometric indicators hardly exists, with previous studies reporting mixed results. The evidence of impacts on other outcomes—for example, dietary quality and incomes—in these studies are also inconclusive since different outcomes are examined in different study contexts (Bird et al., 2019; Osei et al., 2017).

Previous studies also have several limitations. First, most of the studies estimate average effects without analysing possible heterogeneous effects.[2] Understanding heterogeneous effects among different categories of farmers may help design policies with desirable distributional outcomes. Second, many previous studies rely on cross-sectional data which are limited for drawing robust causal inference. Notable exceptions include studies by Olney et al. (2015, 2016), Schreinemachers et al. (2016), Osei et al. (2017), Baliki et al. (2019, 2022), Blakstad et al. (2021, 2022), and Depenbusch et al. (2021, 2022), that used experimental or quasi-experimental designs with panel data. Lastly, studies analysing the effects of agricultural interventions on nutritional

[1]While home garden interventions can contribute to broader farm diversification, the literature on farm diversification and home gardens are distinct because home gardening interventions are typically accompanied with training in agronomy, nutrition, and focus on promoting micronutrient-rich vegetables, but farm diversification may occur without being accompanied by nutrition training (Schreinemachers et al., 2016).

[2]For example, while it is acknowledged that agricultural interventions are more likely to have significant effects when targeted to women and accompanied with nutrition education and women empowerment activities, few studies have examined the effects of targeting women versus men (Ruel et al., 2013; Sharma et al., 2021).

outcomes in India, other parts of South Asia, and among the most vulnerable population groups are limited (Bird et al., 2019; Kadiyala et al., 2014; Pandey et al., 2016; Rammohan et al., 2019). Yet, it is important to study the most vulnerable population groups since they tend to experience severe malnutrition problems when faced with shocks due to their limited resources, low levels of empowerment, and resilience (Akombi et al., 2017).

Our overall objective is to analyse the effects of home gardens on food security, dietary quality, child anthropometry, income and poverty. We contribute to the existing literature in the following ways. First, we provide evidence of impacts of home gardens on a wide range of nutritional and income indicators within the same study. Second, in addition to analysing average effects, we estimate heterogeneous effects of home gardens by gender, education and farm size, and we also compare households with or without children below 5 years of age. Additionally, we use quantile regressions to examine possible distribution issues on food security and income. Third, we use two rounds of panel data covering 4 years, combined with difference-in-difference (DID) regressions to rigorously analyse the impact of home gardens. Lastly, we conduct this study in India among vulnerable tribal groups (further details below), and therefore add to the evidence of the impact of agricultural interventions in India, South Asia, and among vulnerable population groups.

Our focus on India is important for the following reasons. Although India has achieved the status of a middle-income economy, malnutrition is still a pressing public health concern. The global hunger index based on four component indicators (population undernourishment and child stunting, wasting and mortality) ranked India at position 101 out of 116 countries, with a score of 27.5, indicating a serious level of hunger (GHI, 2021). Low intake of fruits and vegetables, less diverse diets, and/or cereal-dominated diets are contributing to poor dietary quality and increased micronutrient deficiencies in India (Choudhury et al., 2020; Meenakshi, 2016). Recent statistics show that per capita consumption of fresh fruits and vegetables in rural and urban India is 160 and 184 g/day, respectively, which is far below the World Health Organisation's (WHO's) recommendation of 400 g/day required to maintain a healthy diet (Choudhury et al., 2020; Minocha et al., 2018). Malnutrition in India contributes to increased prevalence of anaemia among women and children under 5 years (greater than 50%), child stunting (39%), child underweight (33%), child wasting (16%), disability and deaths (Swaminathan et al., 2019).

The remainder of this article is organised as follows. The next section describes the study background, data and key nutritional, income and poverty outcomes used. This is followed by a description of the estimation strategy used to disentangle the average and heterogeneous effects of home gardens on nutritional outcomes in Section 3. Descriptive and estimation results of the effects of home gardens on nutritional outcomes are presented in Section 4. Section 5 concludes.

2 | BACKGROUND AND DATA

2.1 | Study context

We conduct this study in Odisha, India, within the context of the Odisha Particularly Vulnerable Tribal Group Empowerment and Livelihoods Improvement Programme (OPELIP), a programme funded by the International Fund for Agricultural Development (IFAD). OPELIP identified home gardens as an intervention that could potentially improve food and nutrition security among project beneficiaries, namely the particularly vulnerable tribal groups (PVTGs) and other vulnerable population groups (Scheduled Castes and other Scheduled Tribes) in 12 districts in the state of Odisha, India. The programme targeted Scheduled Tribes because they are among the poorest and most vulnerable population groups in rural India (IFAD, 2014). PVTGs are the poorest among the Scheduled Tribes. They also fall behind in key development indicators, such as food and nutrition security, education, and health. Compared to other population groups in

India, Scheduled Tribes, for instance, consume relatively few fresh fruits and vegetables, and are thus more vulnerable to malnutrition challenges (Choudhury et al., 2020).

2.2 | Intervention

Implementation of the home garden intervention among the vulnerable population groups commenced in 2017 and is ongoing. The programme aims to reach 32,000 beneficiaries with home garden interventions to help them increase their production and consumption of highly nutritious home-produced foods, and ultimately improve their food and nutrition security by improving the quality of their diet (IFAD, 2014). Targeted beneficiaries have traditionally grown a wide variety of nutrient-dense crops, such as millets, pulses, fruits and vegetables (IFAD, 2014).[3] However, production of these crops has been falling due to poor seed selection and management, as well as declining soil fertility of lands under *podu* cultivation (shifting cultivation), thereby worsening malnutrition (IFAD, 2014). In this context, home gardens can be an effective strategy to address malnutrition.

In terms of recruitment into the intervention, all households in a programme village, especially PVTG households and women-headed households, were encouraged through Village Development Associations and the programme staff to take up home gardens to produce fruits and vegetables. Participant households were required to own some land to establish the home gardens. The size of the home gardens varied from 40 to 400 m^2 depending on land availability. As of November 2021, about 175 households (9% of our total sample, and 15% [147] of households in programme villages) had adopted home gardens and more farmers will likely adopt home gardens as programme implementation continues. The majority (about 75%) of the home garden interventions were implemented between 2020 and 2021. Thus, potential bias in their estimated effect due to variation in implementation time is likely to be limited.

Programme beneficiaries were offered nutrition training focused on the role of home gardens in nutrition and the importance of consuming diverse diets (through two nutrition models: the *Tiringa Thali* and *7-din 7-ghar* models, which teach the importance of consuming a diverse diet at each meal and harvesting different vegetables on different days of the week, respectively). Agronomic training was tailored for home garden establishment and management and mainly covered topics such as seed and land preparation, watering, fence building, seed and seedling planting, fertiliser application, and harvesting. Each training session lasted for a day and was conducted at a local training centre by trained instructors or frontline workers and included classroom teaching and practical demonstrations. Frontline workers conducted one-on-one follow-up visits on a weekly basis with beneficiaries at their homes to discuss emerging challenges or questions. In addition to training, the programme provided a home garden package that included fencing and watering materials, seeds or seedlings, and farm implements (IFAD, 2014).

2.3 | Farm survey

We use two rounds of data collected from a survey of about 1900 farm households spread across 12 districts in the state of Odisha, India. The baseline and midline surveys were conducted in June 2017 and November 2021, respectively, but both the baseline and midline data referred to the same 1-year reference period to avoid possible seasonal variations in production. An endline evaluation will be conducted in 2024, when the programme implementation is complete. Within the 12 districts of Odisha, OPELIP was implemented in all 17 micro-project areas (MPAs) with

[3] This also implies that cultivation of diverse nutrient-rich fruits and vegetables and other crops in home gardens may not be particularly challenging for the households since they are already familiar with the practice.

the target beneficiaries.[4] MPAs are government entities/zones (smaller than districts), that were formed in the late 1970s and are mandated with the responsibility of facilitating the delivery of public goods and services to Scheduled Tribes, including PVTGs (IFAD, 2017).

A two-stage proportional sampling procedure was used to generate the sample for the household survey at the baseline, following a quasi-experimental study design, since assignment into treatment or control group was not random. In the first stage, proportional stratified sampling was used to determine the number of households to be selected from each of the 17 MPAs covered by the programme. This aimed at ensuring proportional representation of households from all the 17 MPAs, and that variation in geographical and agro-climatic conditions in each of the MPAs is captured. Since sample size calculations at the baseline had shown that 1048 programme households—1.68% of 62,356 overall OPELIP target beneficiary households—would provide sufficient power to detect impact estimates, a proportionate number of households were randomly selected from each of the 17 MPAs based on their population size.

In the second stage, the programme sample of 1048 households was divided by 12 (the minimum number of households to be interviewed in each village based on the sample size computations), generating a total of 87 intervention villages that were randomly selected for the survey. Since there were no MPAs associated with the control/comparison villages (households), 1048 comparison households were selected from outside programme villages or areas, but within the same district and block[5] for comparability (IFAD, 2017). In particular, households were sampled from comparison villages selected using the propensity score matching procedure[6] with three nearest neighbours that matched villages and ensured programme and comparison villages were not significantly different from each other based on a set of 20 village-level covariates. In addition, 87 villages (each with a random sample of 12 households) were sampled for the comparison or control group; hence, the total baseline sample included 2096 households located in 174 villages. However, due to sample attrition (of about 8.5% evenly distributed between the programme and comparison groups), the midline survey round includes observations from 1921 farm households.[7] For this analysis, we use balanced panel data of 1921 households whose data are available in both survey rounds. Our analysis is based on the comparison between households with and without home gardens across programme and comparison villages, while accounting for the differences across programme and comparison villages.

2.4 | Measurement of nutritional, income and poverty variables

Our aim is to analyse the effects of home gardens on: (a) food security, measured in terms of the household dietary diversity score (HDDS) and monthly value of home-produced and consumed food per adult equivalent; (b) dietary quality, measured using minimum dietary diversity (MDD) for children aged 6–23 months, MDD for women (MDD-W), and MDD for men (MDD-M); (c) child anthropometry for children under 5 years; and (d) monthly per-adult equivalent income and income poverty.

To construct the HDDS, we use food consumption recall data. In particular, we use 7-day household food consumption data to construct HDDS as a simple count of the number of food groups consumed by the household in the last 7 days prior to the survey, out of 12 possible

[4]The 12 out of 30 districts in Odisha were selected to be in OPELIP because they have the largest concentration of PVTG households.

[5]A block or *tehsil* is an administrative unit in India that is smaller than a district, but larger than a village.

[6]This PSM procedure was used to establish the sample and was not part of the analysis.

[7]Although the rate of attrition in our sample is relatively small, we test and control for possible attrition bias as a robustness check using an inverse probability weighting procedure following Wooldridge (2002). The procedure entails using a probit regression to calculate the probability for each observation to be included in the midline and then using the probabilities for inverse probability weighting in the DID models. The probit regression used to analyse the association between attrition and socioeconomic variables suggests (not shown for brevity) that attrition did not vary between the programme or comparison group.

food groups including: cereals; roots and tubers; vegetables; fruits; meat; eggs; fish and other sea food; legumes, nuts, and seeds; milk and milk products; oils and fats; sweets; and spices and condiments (Kennedy et al., 2011). The HDDS serves as a robust indicator for food security due to its positive correlation with energy intake (Leroy et al., 2015). Additionally, we compute the monthly value of all home-produced and consumed food per adult equivalent as a further measure and proxy for household food security. Food items were valued using prevailing market price estimates provided by the respondents.

We use 24-hour individual food consumption recall data to construct MDD as the share of children aged 6–23 months who consume at least five out of possible eight food groups (WHO, 2017). MDD is an indicator designed by WHO to assess diet diversity as part of infant and young child feeding (IYCF) practices among children 6–23 months old. We compute MDD-W as the share of women of reproductive age (15–49 years) who consumed at least 5 out of 10 food groups (grains, white roots and tubers, and plantains; pulses (beans, peas and lentils); nuts and seeds; dairy; meat, poultry and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruits and vegetables; other vegetables; and other fruits) in the last 24 h. This indicator is used as a proxy for higher micronutrient intake or diet quality (FAO & FHI 360, 2016). We use the same food group classification for the MDD-W to compute MDD-M as an additional index which has rarely been used in the literature (Gupta et al., 2020). This helps us compare dietary quality for men and women using the same metrics. Overall, we use MDD, MDD-W and MDD-M as proxy indicators for dietary quality. These indicators are only computed in the midline survey round as the relevant data for their computation was not available at the baseline.

To compute child anthropometric measures, we use WHO's (2006) growth references. Accordingly, we compute height-for-age z-scores (HAZ), weight-for-age z-scores (WAZ), and weight-for-height z-scores (WHZ). HAZ measures chronic undernutrition, or stunting, WAZ reflects underweight, and WHZ measures acute undernutrition, or wasting, among children. From the z-scores, we compute the prevalence of stunting, underweight and wasting if HAZ, WAZ and WHZ, respectively, have values that are less than −2 standard deviations (WHO, 2006).

Apart from food security, dietary quality and anthropometric indicators, we also compute household income and 'income poverty'. Household income includes farm and off-farm income (income from employment and self-employment activities of household members, transfers, and land and capital rents). We report household income on a monthly per adult equivalent basis in Indian rupees (INR). We use the FAO's per adult equivalent scales to adjust households of different sizes and composition (age and sex) to a standard unit (adult male equivalent) that allows for direct comparison of different households' food requirements (Weisell & Dop, 2012). Lastly, we define 'income poverty' as a dummy variable that takes a value of one if a household's per adult equivalent income falls below 625 INR per month, and zero otherwise. The threshold of 625 INR was selected as it was the per capita monthly poverty cut-off for households in Odisha in 2017 (IFAD, 2017). For appropriate comparison of all values and monetary computations, year 2021 figures are deflated to year 2017 (base year) figures using the Consumer Price Index (CPI) deflator (multiplied by 0.824) and computed using the CPI for India from the World Bank (2022).

3 | ESTIMATION STRATEGY

3.1 | Average intervention effects

This study evaluates the average effects of home gardens on the indicators described above. Proper identification of the average effects of home gardens requires that we control, to the extent possible, for all factors that may be jointly correlated with the nutritional and income indicators of adopters and non-adopters of home gardens. Given that we rely on observational data with possibility of programme placement and households self-selecting into the home garden intervention, identification of the causal effects of the home gardens may be challenging due to potential endogeneity problems. However, our panel data allows us to observe the sample households across time and rigorously evaluate the effects of home gardens using panel data regression models. In particular, we use the DID estimator to account for unobserved time-invariant confounding factors (Greene, 2012).

An important question is how to define the 'treatment' or home garden intervention variable. When the 'treatment' is defined simply as being in a group of households selected to receive home garden support and compared with a group of households not selected to receive home garden support, it results in the intent-to-treat (ITT) estimator. The ITT estimator does not account for possible non-compliance, which occurs if: not all households earmarked to receive the home garden support are offered support or not all households offered support take it up (Angrist, 2006; Bloom, 2006). In our case, only 15% (147 out of 962) of the households selected to receive the intervention adopted it. This is largely due to delays in programme roll out rather than disinterest in the intervention among households. This level of non-compliance would understate the average effect of the intervention if the ITT estimator were used (Bloom, 2006). Non-compliance is better accounted for by the local average treatment effect (LATE) also known as the treatment-on-the-treated (TOT) effect, which measures the actual effect of having a home garden rather than being in a programme village (Bloom, 2006; Duflo et al., 2007). Moreover, the ITT estimator can be validly estimated in an experimental design, rather than in a quasi-experimental design, as is the case in this study (Bloom, 2006). Hence, we rely on the LATE estimator in our analysis.

Assuming that Y is the outcome of interest (e.g., HDDS, MDD-W and monthly per adult-equivalent income discussed above) and X is the vector of control variables, we can estimate the effect of the home gardens (H) using the DID approach as follows:

$$Y_{it} = \beta_0 + \beta_1 Time_t + \beta_2 H_t + \beta_3 (H_t \times Time_t) + \vartheta X + \alpha D + \varepsilon_{gt}, \quad (1)$$

where β_0 denotes the constant, β_1 captures the time trend or unobserved time effects and β_2 represents the intervention group effects or unobserved effects among home garden adopters relative to non-adopters in the absence of the programme. The coefficient on the interaction term β_3 is our parameter of interest, which estimates the effects of home gardens. The DID estimator β_3 relies on the parallel or common trends assumption, which postulates that in the absence of an intervention (home gardens), the difference between the intervention and non-intervention group is constant over time (Angrist & Pischke, 2008; Cameron & Trivedi, 2005). Although our data does not allow us to explicitly test the parallel trends assumption, we believe the assumption may hold in our case given that baseline and midline characteristics between farmers with and without home gardens were largely similar or follow the same trend (see Table 1). ϑ is the coefficient for the vector of control variables (e.g., age of household head, sex of head, marital status of head, education of head, household size, land size, land title, tropical livestock units, and intervention village dummy), α is the coefficient for the vector of district dummy variables interacted with time to control for possible unobserved time-varying district differences, and ε_{gt} is the error term. Subscripts g and t denote group (adopter or non-adoption status) and time, respectively. DID Poisson regression models are used for models with count outcome variables such as household dietary diversity score, while DID linear regression models are used for models with continuous variables such as income (Wooldridge, 2002).

Since we introduced dietary quality indicators in the midline survey, we only have cross-sectional data for the indicators (MDD, MDD-W and MDD-M). This implies that the DID approach cannot be used, limiting robust analysis of causal effects. We therefore use the propensity score matching (PSM) following Rosenbaum and Rubin (1983) and treatment effects (TE) models following StataCorp (2021) to analyse the impacts of home gardens on the new

TABLE 1 Summary statistics by home garden adoption status

	2017		2021		Pooled sample
	Adopters	Non-adopters	Adopters	Non-adopters	
Variable	Mean	Mean	Mean	Mean	Mean
Age of household head (years)	45.77	46.67	47.85	48.65	47.58
	(12.58)	(13.04)	(12.05)	(12.93)	(12.96)
Female head (%)	10.86	9.74	13.71	13.57	11.71
	(31.20)	(29.65)	(34.50)	(34.26)	(32.16)
Married head (%)	86.86	86.37	82.29	82.25	84.33
	(33.88)	(34.32)	(38.29)	(38.22)	(36.36)
Education of head (years)	2.31	2.56	2.86	3.01	2.77
	(3.71)	(3.82)	(3.91)	(3.99)	(3.90)
Household size (adult equivalent)	4.31*	4.10	4.30***	3.92	4.04
	(1.78)	(1.51)	(1.69)	(1.49)	(1.52)
Farm size (acres)	1.45	1.54	2.05	2.05	1.79
	(1.56)	(2.42)	(1.78)	(3.86)	(3.12)
Has land title (%)	18.29	16.38	22.86***	36.43	25.87
	(38.77)	(37.02)	(42.11)	(48.14)	(43.80)
Regular/settled agriculture (%)[a]	77.14	77.78	90.86	87.92	82.95
	(42.11)	(41.59)	(28.90)	(32.60)	(37.61)
Tropical livestock units (TLUs)	2.76	3.30	2.71	3.09	3.15
	(4.45)	(4.17)	(4.58)	(5.46)	(4.83)
Group membership (membership in farmer or SHG) (dummy)[b]	0.27*	0.21	0.79***	0.65	0.44
	(0.44)	(0.41)	(0.41)	(0.48)	(0.50)
Programme village (dummy)	0.84***	0.47	0.84***	0.47	0.50
	(0.37)	(0.50)	(0.37)	(0.50)	(0.50)
Access to safe drinking water (%)	71.43	75.72	81.14	81.67	78.47
	(45.31)	(42.89)	(39.23)	(38.70)	(41.11)
Improved toilet (%)	30.29	28.75	41.71	39.18	34.15
	(46.08)	(45.27)	(49.45)	(48.83)	(47.43)
Improved source of energy (%)	70.29	74.97	92.57	93.36	83.91
	(45.83)	(43.33)	(26.30)	(24.91)	(36.74)
Number of adopters	9		166		
Observations	175	1746	175	1746	3842

Note: Standard deviations are shown in parentheses.

*, ** and *** significant at 10%, 5%, and 1% level, respectively.

[a]Regular or settled agriculture the opposite of shifting cultivation.

[b]SHG stands for self-help group.

indicators but rely on the DID approach for the indicators observed in two survey periods. The PSM approach compares outcomes of home garden adopters and non-adopters according to the predicted probability of participation in home garden interventions. PSM is superior to a simple comparison of means between adopters and non-adopters in a quasi-experimental study design, with its main limitation being that it only controls for observed confounding factors. PSM is estimated using nearest neighbour matching and our TE model is estimated using inverse probability weighting (IPW). For more details on PSM and TE see Rosenbaum and Rubin (1983) and StataCorp (2021).

3.2 | Heterogeneous treatment effects

For any intervention, the effects may be heterogeneous. Understanding whether an intervention has heterogeneous effects is important from a policy perspective to prevent undesirable distributional effects or inequality. For instance, home gardens could have different nutritional effects on households with less food compared to those with an abundant food supply, a better diet quality and better socioeconomic characteristics. We examine the heterogeneous effects of the home garden intervention by gender of household head, education of household head and farm size, and also compare households with and without children under 5 years of age. Gender, education and farm size were shown to be important determinants of innovation adoption among smallholders; hence differences in these variables may lead to different welfare effects (Kabunga et al., 2012; Lambrecht et al., 2016). To estimate the heterogeneous effects of the home garden intervention among adopters with different socioeconomic characteristics, we modify Equation (1) by interacting the DID estimator with each of the variables ($\boldsymbol{S}$) of interest as shown below:

$$Y_{it} = \beta_0 + \beta_1 Time_t + \beta_2 H_t + \beta_3 \left(H_t {}^* Time_t\right) + \beta_4 (H_t \times Time_t \times S) + \vartheta X + \alpha D + \varepsilon_{gt}, \quad (2)$$

where β_4 is our parameter of interest, which represents the differential effects of the home garden intervention on nutrition and incomes between male- and female-headed households, households with more years of education and those with less years of education, with larger or smaller farm sizes, and households with and without children under 5 years of age, while holding other socioeconomic factors captured in X constant.

In addition to using the interaction terms to analyse heterogeneous treatment effects based on the explanatory variables, we also employ quantile regressions to analyse the effects of home gardens over the distribution of the value of home-produced and consumed food and income.[8] Depenbusch et al. (2022) also used quantile regressions to study the heterogeneous effects of home gardens. Following Powell (2016), we use quantile regression for panel data, which controls for time-invariant unobserved heterogeneity. We specify the quantile regression for panel data model as follows:

$$Qy_{it}(\tau | \boldsymbol{X}_{it}) = \boldsymbol{X}'_{it}\beta(\tau) + \varepsilon_{it\tau}, \quad (3)$$

where $Qy_{it}(\tau|\boldsymbol{X}_{it})$ is the quantile of the outcome variable y_{it} (monthly value of home-produced and consumed food and income per adult equivalent) at quantile τ $(0 < \tau < 1)$ dependent on the vector of control variables $\boldsymbol{X}_{it}$, including participation in the home garden intervention dummy and other covariates. $\beta(\tau)$ is the vector of parameters estimated using the generalised method of moments (GMM), where $\hat{\beta}(\tau)$ is specified as:

$$\hat{\beta}(\tau) = \underset{b \in B}{\operatorname{argmin}} \hat{g}(\boldsymbol{b})' \hat{A} \hat{g}(\boldsymbol{b}), \quad (4)$$

where $\boldsymbol{b}$ is equivalent to the vector of parameters of the control variables $\boldsymbol{X}_{it}$, $\boldsymbol{B}$ is a set of all estimated parameters, $\hat{g}(\boldsymbol{b})$ are the sample moments, and $\hat{A}$ is a weighting matrix for the sample

[8]HDDS, which is a count variable, MDD, MDD-W, MDD-M, and anthropometric indicators computed as percentages or prevalence are not intuitively appealing for the analysis since they are not continuous variables; hence, we exclude these outcomes from the quantile regression analysis, which is suitable for continuous dependent variables.

moments. We estimate $\hat{\beta}(\tau)$ at five different quantiles (τ =0.10, 0.25, 0.50, 0.75, 0.90) for the selected outcome mentioned above.

4 | RESULTS AND DISCUSSION

4.1 | Descriptive statistics

Table 1 presents summary statistics by home garden adoption status for both baseline and midline survey rounds. At least 85% of the sample household heads were men. The mean sample age of the household heads was 46 years at baseline and 48 years at the midline survey. Household heads had about 2.5 years of formal education at baseline and 3 years in the midline survey, with the increment in the midline survey possibly occurring due to changes in the composition of household heads across the two survey rounds. The few years of formal education are plausible because our sample consists of the vulnerable population groups. The sample consists of smallholder farm households with an average farm size of about 2 acres. Comparison of the selected socioeconomic variables between adopters and non-adopters of home gardens shows that adopters have significantly larger families and, as expected, are more likely to have a household member in a self-help group, and are found in villages that were earmarked for promotion of home gardens. For most of the other socioeconomic characteristics, significant differences between adopters and non-adopters are not observed, which suggests that our subsamples of adopters and non-adopters are comparable at least in observed characteristics and can be effectively used to assess impact of home gardens after controlling for possible unobserved and observed confounding factors, as we do with the regressions specified in Equations (1–3).

Table 2 presents the summary statistics of production, sales, food security, dietary quality and anthropometric indicators by adoption status. For the dietary quality indicators, statistics are presented only for the midline survey round due to data limitations as mentioned earlier, but for the other indicators summary statistics are presented for both baseline and midline survey rounds.

These data suggest that adopters had significantly lower food production in value terms than non-adopters at baseline, but the same values of food production are observed for both groups in the midline survey, suggesting a possible improvement in food production among adopters in the midline survey. Sales values are similar between adopters and non-adopters in both survey rounds but are smaller than production values, as expected. Sample households consume about 6 out of 12 food groups on average. Adopters of home gardens consume significantly fewer food groups at baseline, but consume about the same number of food groups compared to non-adopters in the midline survey round. The monthly value of home-produced and consumed foods per adult equivalent is significantly lower for adopters compared to non-adopters in both survey rounds. For both adopters and non-adopters, the quantity of home-produced foods increased in the midline survey as shown by the higher values of home-produced foods and consumed foods in the midline survey compared to the baseline round, after accounting for inflation. However, adopters experienced relatively greater increase in home-produced and consumed foods (31%) compared to non-adopters (20%).

Table 2 also shows that about 37% of all children aged 6–23 months consumed at least five out of eight food groups (a minimally diverse diet with adequate micronutrients or higher quality diet). A significantly larger share (54%) of children aged 6–23 months in households with home gardens consumed a minimally diverse diet compared with only 34% of children aged 6–23 months in households without home gardens. Only 20% of men and women aged 15–49 years in the sample consumed an adequate diet, in terms of micronutrients (at least 5 out of 10 food groups). In terms of child anthropometry, the results do not show any significant differences between adopters and non-adopters of home gardens. Prevalence of stunting and

TABLE 2 Production, sales, and food and nutrition security indicators by adoption status

	2017		2021		
	Adopters	Non-adopters	Adopters	Non-adopters	Pooled
Indicators	**Mean**	**Mean**	**Mean**	**Mean**	**Mean**
Value of production and sales					
Value of home-produced food per annum (1000 INR)	41.43*	49.19	60.92	63.86	56.04
	(50.58)	(54.55)	(88.67)	(79.30)	(68.85)
Value of home-produced food sold per annum (1000 INR)	1.81	4.37	10.59	8.99	6.64
	(7.45)	(20.55)	(36.26)	(32.39)	(27.15)
Food security indicators					
Household dietary diversity score (HDDS) (0–12)	5.56**	5.86	5.24	5.19	5.51
	(1.76)	(1.59)	(1.19)	(1.25)	(1.47)
Monthly value of home-produced and consumed food per adult equivalent (INR)	84.93**	127.75	110.97***	153.22	136.61
	(181.69)	(266.48)	(178.32)	(208.93)	(235.25)
Observations	175	1,746	175	1,746	3,842
Dietary quality indicators					
Minimum dietary diversity (MDD) (%)			54.17*	34.31	37.27
			(50.90)	(47.65)	(48.50)
Minimum dietary diversity for men (MDD-M) (%)			17.09	20.81	20.47
			(37.76)	(40.61)	(40.36)
Minimum dietary diversity for women (MDD-W) (%)			16.57	20.23	19.89
			(37.29)	(40.18)	(39.93)
Observations			169	1,686	1,855
Child anthropometry					
Prevalence of stunting (%)	30.00	45.85	50.00	45.25	45.42
	(47.02)	(49.92)	(50.45)	(49.84)	(49.82)
Prevalence of underweight (%)	30.00	44.04	41.07	41.00	41.83
	(47.02)	(49.73)	(49.64)	(49.24)	(49.36)
Prevalence of wasting (%)	30.00	30.32	8.93	15.50	20.85
	(47.02)	(46.05)	(28.77)	(36.24)	(40.65)
Observations	20	277	56	400	753

Note: Standard deviations are shown in parentheses.

*, ** and *** significant at 10%, 5%, and 1% level, respectively.

underweight vary greatly among adopters across the two survey rounds, possibly due to the relatively small sample of adopters, which may skew the means away from the true mean. On average, the prevalence of stunting and underweight are between 41% and 46% in both survey rounds, but the prevalence of wasting reduced by almost one-half, from around 30% at baseline to less than 15% in the midline survey round.[9]

Table 3 presents summary statistics of income and income poverty outcomes by adoption status and year of survey. The results show that the monthly mean per adult equivalent income

[9]In both survey rounds, the anthropometric indicators are higher, except for wasting, than those reported by the National Family Health Survey (NFHS) 5, 2019–2021 for the state of Odisha, which shows that between 2019 and 2021, 31% of the children under 5 years were stunted, 29.7% were underweight and 18.1% were wasted (NFHS 5, 2019–2021). This is probably because our study largely focuses on the PVTGs and Scheduled Tribes (STs) which are more vulnerable to malnutrition challenges as they tend to consume less nutritious diets (Choudhury et al., 2020).

TABLE 3 Income and income poverty by adoption status

Indicator	2017 Adopters Mean	2017 Non-adopters Mean	2021 Adopters Mean	2021 Non-adopters Mean	Pooled sample Mean
Income, monthly per-adult equivalent (INR)	377.12	434.51	1,381.63***	1,132.17	792.09
	(869.16)	(829.21)	(1241.35)	(1163.11)	(1079.53)
Income poor (%)	85.14	80.13	36.00**	46.16	62.91
	(35.67)	(39.92)	(48.14)	(49.87)	(48.31)
Observations	175	1746	175	1746	3842

Note: Standard deviations are shown in parentheses.

*, ** and *** significant at 10%, 5%, and 1% level, respectively.

of sample households more than doubled in the midline survey, increasing from around 429 INR at baseline to 1155 INR in the midline survey. At baseline, the difference in monthly mean per adult equivalent incomes of adopters and non-adopters of home gardens was not statistically significant. However, in the midline survey, adopters had statistically significant higher monthly per adult equivalent incomes compared to non-adopters. More than 80% of the sample was income poor at baseline, but in the midline survey, the prevalence of income poverty declined significantly to around 45%. Interestingly, the prevalence of poverty among adopters (36%) was significantly lower compared to non-adopters (46%), suggesting that home gardens may have contributed to improved incomes and reduced the prevalence of income poverty.

Comparisons between adopters and non-adopters of home gardens do not show clear differences between adopters and non-adopters of home gardens except that having home gardens is positively correlated with higher incomes and a lower prevalence of income poverty. However, these results cannot be interpreted as causal effects because they do not control for possible confounding factors. We control for confounding factors in the following subsections using the regression models explained in Section 3. We present and discuss results without attrition-weighting in the following subsections. However, for comparison, we also show attrition-weighted results in Tables A1–A3. Both sets of estimates are very similar, which underlines that attrition is not a major problem in our analysis.

4.2 | Effects of home gardens on food security

Table 4 presents the effects of home gardens on food security measured in terms of HDDS and monthly value of home-produced and consumed foods per adult equivalent using two rounds of panel data. In Column (1) of Table 4, we first show the results of the effect of home gardens on the total value (quantity) of produced food as a possible mechanism for improved food security through direct consumption of available home-produced food. Column (1) shows that having a home garden significantly increases annual home-produced food by 88%, thus increasing the probability of greater food security among adopters of home gardens.[10] The estimate in Column (2) of Table 4 suggests that having a home garden increases the actual monthly value of home-produced and consumed food per adult equivalent by 74.3 INR, a 54% increase when compared to the sample's average monthly value of home-produced and consumed food per adult equivalent.

[10]Percentage of the treatment effect for the log-transformed outcome is computed using the formula $100\left(e^{ATT}-1\right)$, where e is the exponential (Kennedy, 1981).

TABLE 4 Effect of home gardens on value of food home-produced, household dietary diversity score, and value of home-produced and consumed food

Variable	(1) Value of home-produced food per annum (log)	(2) Per adult equivalent monthly value of home-produced and consumed food (INR)	(3) Household dietary diversity score (0–12)
Time (Year 2021)	−0.72*	30.47	−0.55***
		(42.16)	(0.05)
Home garden × time	0.63**	74.35***	0.10***
		(23.82)	(0.03)
Control variables	Yes	Yes	Yes
Constant	7.12***	174.44	1.82***
	(0.47)	(36.54)	(0.05)
Observations	3842	3842	3842
R-squared	0.32	0.13	

Note: Time variable captures the time trend. Interaction between home garden dummy and time dummy variable captures the effect of home gardens household dietary diversity score. Columns (1) and (2) estimated using DID linear regressions, Column (3) estimated using DID Poisson regression, are shown with robust standard errors clustered at the village level in parentheses. Control variables include: age of household head, age of head squared, sex of head, marital status of head, education of head, household size, land size, squared land size, land title, TLU, and district dummies.

*, ** and *** significant at 10%, 5%, and 1% level, respectively.

Column (3) of Table 4 presents the effects of home gardens on HDDS. The coefficient estimate shows that having a home garden significantly increases HDDS by 10%. This result is plausible and consistent with the results of previous studies which have shown that home gardens contribute to improved dietary diversity and food security (Blakstad et al., 2021; Rammohan et al., 2019). Overall, the results in Table 4 show evidence of the positive effects of home gardens on food security and are consistent with previous literature which suggested that home gardens can contribute to improved food security by increasing production (food availability), consumption of home-produced foods and dietary diversity (Baliki et al., 2022; Blakstad et al., 2022; Depenbusch et al., 2022; Rammohan et al., 2019).

4.3 | Effects of home gardens on dietary quality and child anthropometry

Table 5 presents the results of the association between home gardens and dietary quality measured in terms of MDD, MDD-M and MDD-W using the midline survey data. For robustness checks, we present the results of ordinary least squares (OLS) in Column (1), PSM estimated using nearest neighbour matching in Column (2), and the TE model estimated using IPW in Column (3). The estimation results are consistent across the different models and show that having a home garden has no effect on the share of children aged 6–23 months who consume diets of minimal acceptable level of diversity. However, having a home garden significantly increases the probability of consuming a minimally acceptable diverse diet by around 5–7 percentage points for men and 4–6 percentage points for women. These results suggest that home gardens contribute to improved dietary quality among men and women of reproductive age, and are consistent with the results of the study by Blakstad et al. (2021), which showed that home gardens contribute to improved dietary quality among women of reproductive age.

In regard to child anthropometry, Columns (1)–(3) of Table 6 show that having a home garden does not have a significant effect on the prevalence of child stunting, underweight or wasting. Although insignificant, they are consistent with the results of previous studies which showed that home gardens do not have an effect on child anthropometry (Bird et al., 2019; Osei

TABLE 5 Effect of home gardens on dietary quality (midline sample only)

Indicator	(1) OLS ATT(SE)	(2) Neighbour matching ATT(SE)	(3) IPW ATT(SE)	(4) Observations
Minimum dietary diversity (MDD) (%)	16.71	7.62	3.35	161
	(15.28)	(24.99)	(14.42)	
Minimum dietary diversity for men (MDD-M) (%)	5.11*	7.48**	4.99*	1,715
	(2.81)	(3.30)	(2.69)	
Minimum dietary diversity for women (MDD-W) (%)	4.23*	5.95*	4.52*	1,855
	(2.47)	(3.54)	(2.54)	

Note: Point estimates are estimated using OLS and propensity score matching. Robust standard errors appear in parentheses. Control variables include: age of household head, age of head squared, sex of head, marital status of head, education of head, household size, land size, squared land size, land title, TLU, district dummies.

* and ** significant at 10% and 5% level, respectively.

TABLE 6 Effect of home gardens on child anthropometry

Variable	(1) Prevalence of stunting (%)	(2) Prevalence of underweight (%)	(3) Prevalence of wasting (%)
Time (Year 2021)	30.47**	29.92	9.65
	(14.62)	(18.22)	(13.56)
Home garden × time	23.10	13.13	−9.949
	(14.02)	(14.19)	(11.051)
Control variables	Yes	Yes	Yes
Constant	66.76***	65.87***	32.11*
	(19.47)	(21.16)	(18.22)
Observation	753	753	753
R-squared	0.10	0.08	0.11

Note: Time variable captures the time trend. Interaction between home garden dummy and time dummy variable captures the effect of home gardens on child anthropometry. Coefficients are estimated using DID, and are shown with robust standard errors clustered at the village level in parentheses. Control variables include: age of household head, age of head squared, sex of head, marital status of head, education of head, household size, land size, squared land size, land title, TLU, group membership, access to safe drinking water, access to improved toilet, access to improved source of energy, district dummies.

*, ** and *** significant at 10%, 5%, and 1% level, respectively.

et al., 2017). The lack of significant effects of home gardens on child anthropometry may be due to the complexity of the pathways by which the programmes influence nutritional outcomes (Osei et al., 2017). For instance, home garden interventions may need to be accompanied by improvements in sanitation, family planning, nutrition education and women's empowerment to have or strengthen their positive effect on diets and nutrition (Luna-González & Sørensen, 2018).

4.4 | Effects of home gardens on income and income poverty

Table 7 shows the effects of home gardens on monthly per adult equivalent income and income poverty. In Column (1) of Table 7, we first show results of the effect of home gardens on the value of food sold (sales) as a possible pathway for improved income. Column (1) shows that having a home garden significantly increases annual food sales by 101%, thus increasing incomes among adopters of home gardens. The estimate in Column (1) of Table 7 suggests that having a

TABLE 7 Effect of home gardens on value of sales, income and income poverty

Variable	(1) Value of food sold per annum (log)	(2) Per adult equivalent monthly income (INR)	(3) Income poor (%)
Time (Year 2021)	1.55	126.84	−6.33
	(0.51)	(102.46)	(6.00)
Home garden × time	0.70*	290.28*	−11.66**
	(0.39)	(156.19)	(5.19)
Control variables	Yes	Yes	Yes
Constant	−0.48	143.33	85.48***
	(0.65)	(147.42)	(6.374)
Observation	3842	3842	3842
R-squared	0.21	0.28	0.29

Note: Time variable captures the time trend. Interaction between home garden dummy and time dummy variable captures the effect of home gardens on income and income poverty. Coefficients are estimated using DID, and are shown with robust standard errors clustered at the village level in parentheses. Control variables include: age of household head, age of head squared, sex of head, marital status of head, education of head, household size, land size, squared land size, land title, TLU, group membership, district dummies.
*, ** and *** significant at 10%, 5%, and 1% level, respectively.

home garden increases monthly per adult equivalent income by 290 INR, which translates to a 37% gain when compared to the total sample's average per adult equivalent income. The sizeable positive effects of home gardens on income also seem to contribute significantly to income poverty reductions. The coefficient estimate in Column (2) implies that having a home garden reduces the probability of falling below the poverty line by 11.7 percentage points.

To this point, our results show that on average, home gardens contribute to improved food security (higher value of food production, value of home-produced and consumed foods per adult equivalent, and household dietary diversity), dietary quality of adults, sales and income. Home gardens also have a poverty-reducing effect. Our results are plausible and consistent with the literature which suggests that home gardens contribute to improved food security by increasing household food supply and consumption, improved dietary quality of adults through consumption of diverse diets with higher micronutrient adequacy, higher income through sale of surplus production from the home gardens, and also reduces household poverty (Blakstad et al., 2021; Tesfamariam et al., 2018; Whitney et al., 2018).

4.5 | Heterogeneous effects of home gardens

The results in the previous subsection focused on the average effects of home gardens. In this subsection, we explicitly analyse the heterogeneous effects of home gardens using the estimation procedures described in Section 3 to better understand whether the effects differ by the selected socioeconomic characteristics and outcomes.

Table 8 presents the estimation results of the heterogeneous effects of home gardens on food security, dietary quality, income and income poverty. For brevity, only the interaction effects or coefficients of interest are shown for each selected socioeconomic (gender, education, land size, children under five) and outcome variable. In all the models, except for gender (which shows that female-headed households had significantly higher per adult equivalent incomes (725 INR more) compared to male-headed households), the interaction terms are statistically insignificant, which implies that home gardens do not have heterogeneous effects with respect to education, land size, or whether households have children under 5 years of age.

TABLE 8 Heterogeneous effects of home gardens on food security, dietary quality, income and income poverty

Variables	Household dietary diversity (0–12)	Monthly value of home-produced food per adult equivalent (INR)	Minimum dietary diversity (%)	Minimum dietary diversity-for women (%)	Minimum dietary diversity for men (%)	Income, monthly per-adult equivalent (INR)	Income poor (%)
Gender (female-headed household)	0.03	30.72	−0.99	−1.11	−0.61	725.97**	−12.91
	(0.06)	(51.29)	(1.48)	(0.96)	(1.25)	(362.40)	(9.94)
Land size (acres)	−0.00	−3.21	−0.00	−0.03	−0.01	54.77	−0.17
	(0.02)	(9.37)	(0.21)	(0.05)	(0.06)	(58.09)	(2.44)
Education (years)	−0.00	0.34	−0.04	−0.02	−0.02	−16.99	1.62
	(0.01)	(5.47)	(0.05)	(0.03)	(0.03)	(33.03)	(1.27)
Household with child under five (dummy)	−0.08	−49.01		0.04	0.05	−24.91	−2.76
	(0.06)	(45.37)		(0.29)	(0.27)	(182.64)	(8.77)

Note: Coefficients are estimated using DID regressions and are shown with robust standard errors clustered at the village level in parentheses. For brevity, only coefficients of interest (interaction terms between home gardens and socioeconomic variables and time) are shown. Control variables include: age of household head, age of head squared, sex of head, marital status of head, education of head, household size, land size, squared land size, land title, TLU, district dummies.

** significant at 5% level, respectively.

TABLE 9 Effects of home gardens on different quantiles of food security, income and income poverty

	Quantile				
Variables	0.1	0.25	0.5	0.75	0.9
Monthly value of home-produced food per adult equivalent (INR)	5.13e−16***	6.84e−15***	4.89*	25.26	61.59*
	(1.89e−16)	(2.36e−15)	(2.68)	(38.72)	(33.42)
Income, monthly per-adult equivalent (INR)	0.02**	96.68***	227.92***	539.62***	718.71***
	(0.01)	(29.71)	(41.81)	(135.28)	(108.54)

Note: Coefficients are estimated using quantile regression for panel data, and are shown with standard in parentheses. Control variables include: age of household head, age of head squared, sex of head, marital status of head, education of head, household size, land size, squared land size, land title, TLU, district dummies.

*, ** and *** significant at 10%, 5%, and 1% level, respectively.

Heterogeneous effects may occur due to differences in technology adoption, access to information and extension, education and/or other resources by gender (Ogutu et al., 2020). In this study, both male and female farmers who adopted the home gardens had an opportunity to access information/agricultural training and initial resources to start home gardens. Thus, the homogeneous results by education are plausible because there may not be any differences in knowledge for management of the home gardens to cause a differential effect. Interestingly, the results suggest that when women are given equal access to resources for home gardens, it leads to significantly higher incomes among female-headed households compared to male-headed households. This suggests that home gardens can help boost incomes of often cash- or income-constrained female-headed households more than it would for male-headed households. The homogeneous results by land size are also plausible since the establishment of home gardens only required at least 40 m^2 (0.01) acres of land located close to the household, which almost all farmers could access considering their land sizes.

Table 9 presents results of the heterogeneous effects of home gardens on the monthly per adult equivalent value of home-produced and consumed foods and the monthly per adult equivalent income estimated using quantile regressions. The 0.10 quantile represents the poorest, whereas the 0.90 quantile represents the richest sample households based on the two outcome variables. Results show that having a home garden has significant positive effects on the monthly per adult equivalent value of home-produced and consumed foods and on the monthly per adult equivalent income in all quantiles, except among the poorest sample (quantile 0.10). However, the gains in per adult equivalent value of home-produced and consumed foods and monthly per adult equivalent income for the poorest households are smaller than those for the richest households. Hence, our results suggest that home gardens contribute to improved food security and income, but may not improve inequality, at least among our vulnerable sample.

5 | CONCLUSION

Home gardens have been part of recent food-based interventions aimed at stimulating changes in dietary patterns and improving nutrition. However, evidence of the effects of home gardens on food security, dietary quality, child anthropometry and income is limited, especially among vulnerable population groups. We conduct this study to examine whether such interventions work in resource-poor settings and add to the existing literature by analysing the average effects of home gardens on food security, dietary quality, child anthropometry, income and poverty using panel data. Moreover, we analyse heterogeneous effects of home gardens by gender, education and farm size, and compare households with or without children below 5 years of age. We also estimate heterogeneous effects of home gardens on food security and income using quantile regressions to examine possible inequalities. Our study is conducted in Odisha, India among the vulnerable tribal groups, and therefore contributes to the evidence on the impact of agricultural interventions in India and South Asia, as well as among vulnerable population groups.

The results show that home gardens increase food security (household dietary diversity score, home-produced and consumed food), and the dietary quality of men and women, but have no effect on children's dietary quality. Our results are consistent with the literature that show home gardens contribute to improved food security and dietary quality by increasing production and consumption of home-produced foods (Blakstad et al., 2021; Depenbusch et al., 2022). Consistent with previous studies, results show that home gardens do not have significant effects on the prevalence of child stunting, underweight and wasting (Bird et al., 2019; Osei et al., 2017). Results also suggest that home gardens increase monthly per adult equivalent incomes and reduce the probability of falling below the poverty line. Heterogeneous impact analysis results show that having a home garden increases food security (home-produced and consumed foods) and monthly per adult equivalent income in all quantiles, but the gains for the poorest households are smaller than those for the richest households, which suggest that home gardens contribute to improved food security and income but may also increase inequality.

We conclude that home gardens can improve food security, dietary quality and income in rural farming communities including vulnerable population groups. Our findings also suggest that home gardens can be a poverty-reducing strategy for resource-poor farmers and vulnerable population groups. However, complementary interventions will be needed to improve children's dietary quality and anthropometry. Promotion of home gardens in India can help curb widespread malnutrition problems, such as anaemia in women, by improving the quality of diets that are typically less diverse, dominated by cereals, and/or characterised by low intakes of fruits and vegetables (Choudhury et al., 2020; Meenakshi, 2016). Home gardens can also complement government programmes, such as the National Nutrition Mission, to improve nutrition and also contribute toward achievement of the Sustainable Development Goals, especially Goals 1–3 (no poverty, zero hunger, and good health and well-being) (Suri, 2020).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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