



OPEN ACCESS

EDITED BY

Evangelos D. Lioutas,
International Hellenic University, Greece

REVIEWED BY

John Franklin Leslie,
Kansas State University, United States
Sina Ahmadi Kaliji,
University of Bologna, Italy

*CORRESPONDENCE

SubbaRao M. Gavaravarapu
✉ subbarao.gm@icmr.gov.in

[†]These authors share first authorship

RECEIVED 27 September 2024

ACCEPTED 15 January 2025

PUBLISHED 12 February 2025

CITATION

Jaleel A, Chukkala SGS, Sriswan R, Panda H, Singnale P, Meshram II, Avula L, Hariharan GN, Arlappa N and Gavaravarapu SM (2025) Cultivating nutrition: exploring participants' perspectives on nutrition gardens and nutrition education program in rural Tamil Nadu and Odisha, India. *Front. Sustain. Food Syst.* 9:1502711. doi: 10.3389/fsufs.2025.1502711

COPYRIGHT

© 2025 Jaleel, Chukkala, Sriswan, Panda, Singnale, Meshram, Avula, Hariharan, Arlappa and Gavaravarapu. This is an open-access article distributed under the terms of the [Creative Commons Attribution License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Cultivating nutrition: exploring participants' perspectives on nutrition gardens and nutrition education program in rural Tamil Nadu and Odisha, India

Abdul Jaleel^{1†}, SuryaGoud S. Chukkala^{1†}, Raja Sriswan¹, Hrusikesh Panda¹, Pooja Singnale², Indrapal I. Meshram¹, Laxmaiah Avula¹, G. N. Hariharan³, Nimmathota Arlappa¹ and SubbaRao M. Gavaravarapu^{1*}

¹National Institute of Nutrition (ICMR-NIN), Hyderabad, India, ²Krishi Vigyan Kendra (KVK), Anjaw, Arunachal Pradesh, India, ³M S Swaminathan Research Foundation (MSSRF), Chennai, India

Malnutrition persists as a critical public health concern in India, aggravated by widespread nutrition insecurity due to lack of dietary diversity. Integrating the promotion of nutrition gardens with nutrition education offers a promising strategy to mitigate these challenges, particularly among vulnerable populations. This paper examines the perceptions of households participated in an intervention to promote nutrition-sensitive agriculture and improve nutrition education to combat undernutrition in small-scale farming households in rural India. Using a mixed-methods approach, data were collected from participants in Tamil Nadu and Odisha through structured interviews, key informant interviews, and focus group discussions. The qualitative data were thematically analysed, and a SWOT analysis was conducted to assess the intervention's strengths, weaknesses, opportunities, and threats. The findings show that by integrating nutrition-sensitive approaches into agricultural activities, the intervention has transformed traditional home gardening practices by diversifying homegrown produce. Participants highly valued the training sessions, and the provision of seeds and saplings, which facilitated the establishment of nutrition gardens and improved nutrition-related knowledge. However, while many participants reported improved nutrition knowledge, improvements in dietary diversity and overall nutrition were less commonly reported. Achieving a sustained impact will require context-sensitive implementation, sustained engagement, and addressing structural barriers.

KEYWORDS

nutrition garden, nutrition education, food security, diet diversity, nutrition sensitive agriculture, India

1 Introduction

Hunger and malnutrition remain pressing global challenges. Recent assessments of global hunger in 2023 highlight the lack of substantial progress toward achieving the Sustainable Development Goal (SDG) of Zero Hunger, with Asia accounting for the highest numbers (FAO, IFAD, UNICEF, WFP and WHO, 2024). In India, malnutrition—including widespread micronutrient deficiencies—affects all age groups, with children and women being particularly vulnerable. Among children aged 1–4 years, 32% suffer from iron deficiency nationally, with

state-level prevalence ranging from 4.2 to 67.2% in different states. Deficiencies of other major vitamins and minerals are similarly concerning (MoHFW, UNICEF, Population Council, 2019). These micronutrient deficiencies exacerbate the malnutrition crisis, resulting in high levels of stunting (35.5%), wasting (19.3%), and underweight (32.1%) among children aged 0–59 months, with significant variations between states (IIPS, ICF, 2021).

To address these pressing issues, there has been growing focus on strengthening local food systems and adopting nutrition-sensitive agricultural practices, alongside the implementation of other policies and programs (IFAD, 2015; Niñez, 1987; Guell et al., 2021; IGSSS, 2021; Garrity et al., 2024; FAO, 2018). Nutrition gardens, which focus on cultivating nutrient-dense vegetables and fruits, are recognised as a promising approach to ensuring year-round access to a diverse and balanced diet rich in essential macro- and micronutrients (Galhena et al., 2013; Osei et al., 2017; Sharma et al., 2022; Ferdous et al., 2016). By improving access to adequate, safe, and nutritious food, these gardens contribute to the four dimensions of food and nutrition security: availability, accessibility, utilization, and stability (Galhena et al., 2013; Lal, 2020; Bhullar, 2021; Baliki et al., 2023; Hume et al., 2022; Nair et al., 2015; Tontisirin et al., 2002; Konapur et al., 2022; Wendt et al., 2019; Bhutta et al., 2008).

However, the potential of nutrition gardens may remain unrealized without complementary nutrition education (Osei et al., 2017). Nutrition education promotes awareness of balanced diets, encourages healthier food choices and attitudes, and enhances sustainable, health-promoting behaviors and practical skills (Piscopo, 2019; Pem and Jeewon, 2015; FAO, 2014). This approach holds particular relevance in India, where agriculture is the primary livelihood for most rural households (Bamji et al., 2021). Nutrition gardens along with nutrition education have the potential to reform traditional Indian diets, which are predominantly cereal-based and often lack adequate vegetables, fruits, legumes, and animal-sourced foods (Unisa et al., 2021; Shankar et al., 2017; Tak et al., 2019; Choudhury et al., 2020). Evidence from various countries demonstrates that nutrition education and advocacy can motivate small-scale and marginal farmers to grow and consume homegrown fruits and vegetables, thereby improving household dietary diversity (Palar et al., 2019; Angeles-Agdeppa et al., 2019; Bamji et al., 2021; Bamji et al., 2022; Bushamuka et al., 2005).

In this context, an intervention named—*Food-Based Nutritional Security for Rural Households through Capacity Building and Establishment of Nutri-Gardens*—was conceptualized and implemented in rural Tamil Nadu and Odisha, India. This program sought to combat undernutrition among small and marginal farming households by empowering participant households to establish nutrition gardens and enhancing their knowledge of nutrition-sensitive agriculture, balanced diets and optimal nutrition practices.

This paper evaluates the implementation of the Nutrition Garden program by examining participants' perspectives across three key areas: their readiness and motivation to continue the program (acceptability), their perceptions of improved nutrition knowledge, dietary diversity, and nutrition outcomes (effectiveness), and their ability to maintain and manage the gardens in the future (feasibility). This analysis emphasized the often-overlooked practicalities of implementation and the challenges participants face, which can impede the program's success. The findings also provide actionable insights for improving program design, optimizing impact, and

informing the development of scalable nutrition garden initiatives. Given that research on nutrition gardens and education in India has predominantly focused on Eastern India, particularly among tribal populations (Singh et al., 2023; Bucher and Bucher, 2017; Prost et al., 2022), this program was implemented in two distinct regions—South and East India—each characterized by diverse socio-economic, demographic, and cultural profiles. This approach enabled a comparative analysis of the program's acceptability, effectiveness, and feasibility in different cultural context. The goal was to advance the field by providing practical recommendations for designing and implementing similar interventions across varied settings.

1.1 About the program

The Nutrition Garden program was implemented among small-scale and marginal farming households in various regions of India, including Tamil Nadu, and Odisha. It aims to ensure a consistent, year-round supply of nutrient-rich foods for these households, while also providing nutrition education. The program was implemented in selected districts using two primary approaches: i) promoting nutrition-sensitive agricultural practices through demonstrations and the distribution of location-specific, nutrient-rich plants, and ii) delivering nutrition education through targeted capacity-building efforts.

To ensure effective implementation of the program in the targeted communities, local partners were selected based on their presence and influence within the communities. These partners were responsible for establishing nutrient-rich plant gardens, featuring live collections of nutrient-dense and biofortified plants. They provided farmers with access to plant varieties that could be incorporated into their agricultural practices. Farmers were encouraged to replicate these nutrition garden models in their backyards through training on cultivation techniques, nutrition education, and exposure visits to model gardens. The produce from these gardens was intended primarily for household consumption, thereby enhancing dietary diversity and meeting the nutritional needs of farming families. *Krishi Vigyan Kendras* (KVKs) in Tamil Nadu and MSSRF in Odisha were identified as implementing partners. The program's implementation was supported by grassroots-level workers known as Community Hunger Fighters (CHF). They played a key role in organizing the communities, including the formation of women's Self-Help Groups (SHGs), through which the nutrition garden program was promoted. Additionally, they facilitated the training programs.

The nutrition education component ensured household participation, sustained engagement with the program, and timely access to essential farming and nutrition knowledge. To support this initiative, the program enlisted subject specialists from State Agriculture Universities, KVKs, and progressive farmers as resource persons. These experts conducted training sessions on topics such as soil health, cultivation methods, making of organic fertilizers and pesticides, and importance of diet diversity, etc. The sessions were structured and presented in a sequential manner. The training content was standardized across Tamil Nadu and Odisha, with plans to conduct two sessions each month: the first focusing on agricultural practices and the second on nutrition awareness. The program provided only the initial growing materials, and focused primarily on capacity-building activities. At the time of evaluation, the program

had been in operation for 36 months. Its maturity was assessed based on its structure, design, consistency of implementation, adherence to established processes, and the extent of participants' adoption of prescribed practices.

2 Methodology

2.1 Study design

This study adopted a community-based mixed-methods approach, integrating both quantitative and qualitative research methods. The initial phase involved a cross-sectional quantitative survey of participant households to gather data on their overall profile, including the duration of their involvement in the program, the benefits received, the number of training sessions attended, and other relevant details, such as the types of seeds or saplings received and cultivated under the program, as well as the crop yield obtained and consumed from the cultivation. Following this, a qualitative inquiry was conducted to gain insights into participants' perspectives on various aspects of the program. This qualitative component focused on understanding participants' perceptions of the program's ease of use, perceived benefits like improvements in nutrition-related knowledge, dietary diversity, and nutritional outcomes, and the challenges associated with maintaining nutrition gardens.

2.2 Study participants and sampling

This study was conducted among small scale and marginal farming households participating in the nutrition garden program across two districts: Tiruvallur in Tamil Nadu, South India, and Koraput in Odisha, Eastern India. Assuming a 30% prevalence of stunting (height-for-age $< -2SD$) among children aged 0–59 months, a 95% confidence interval, a 5% absolute precision, and a design effect of 1.5, the initial sample size required was calculated to be 243 households with at least one child under 5 years of age. To account for a potential 10% non-response rate, the total sample size was increased to 270 households. To ensure equal representation of the two states, the sample was divided equally, with 135 households from each state. For the quantitative component of this study, a total of 137 households from Tiruvallur and 138 households from Koraput were selected.

The selection of villages and households involved two key steps. First, a detailed list of all villages where the program was being implemented was compiled, along with a list of participating households in each village. Using these sampling frames, 20 villages were selected from each district for data collection. Within each selected village, seven households were randomly selected from the list of program participants. The randomization process was conducted using the "RAND()" function in Excel to ensure unbiased selection. Data collection was conducted with adult women from the selected households.

For the qualitative study, data collection was carried out at two levels: i) people at the program design and implementation level, and ii) the participant level. At the implementing agency level, through Key Informant Interviews (KIIs), the key informants provided insights into the intended objectives, design of the program including the

content of the trainings, expected outcomes, implementation strategy, scaling-up plans, and other pertinent details. To gain a comprehensive understanding of participant households' perceptions of the Nutrition Garden program, various dimensions were explored through Focus Group Discussions (FGDs). These included the community's traditional practice of maintaining nutrition gardens, the innovative features of the current program, perceived changes in the diversity of fruits and vegetables grown in the past and present, perceived improvements in household dietary diversity, additional efforts required to participate in the program, challenges encountered in maintaining the gardens, awareness of balanced nutrition and nutritional education, and the program's sustainability beyond the support provided by the implementing agency. For this purpose, a subset of households that were participating in the Nutrition Garden program, but were not part of the quantitative study was selected. The primary respondents for this were home food preparers, usually women.

As part of the qualitative data collection, 12 Key Informant Interviews (KIIs) were conducted (six in Tamil Nadu and six in Odisha). Additionally, 16 FGDs were held (eight in Tamil Nadu and eight in Odisha). Theoretically, it is recommended to conduct at least three or four FGDs to obtain valid results on any topic. In this study, we conducted eight FGDs at each site and stopped further sessions as no new themes or insights were emerging.

2.3 Data collection

Quantitative data were collected by trained staff using a pre-tested structured interview schedule. For qualitative data collection, Key Informant Interviews (KIIs) were guided by a list of open-ended questions. Focus Group Discussions (FGDs) were held with women from participating households using a content-validated and pre-tested thematic guide consisting of eight questions arranged from general to specific. These women were contacted through SHGs promoted by the local implementing agencies. The agencies selected specific SHGs based on their confidence that the members of the SHG, being familiar with the program, actively involved, and known for their willingness to share opinions, would make ideal participants and volunteer about 2 h of their time. The quantitative and qualitative tools are included as [Supplementary materials](#).

Participants were invited to a common location in the village, most often a school, for the FGD. During the invitation, it was clearly explained that participation was voluntary, and the objectives of the study were communicated to potential participants. FGDs were facilitated by a team consisting of a trained moderator and a note-taker, both of whom followed standardized procedures for conducting FGDs.

Participants were seated in a semicircular arrangement, with the moderator positioned at the center to facilitate engagement. The moderator began the discussion by welcoming participants, introducing both the moderator and the note-taker, and explaining the topic of discussion along with the purpose of the research. To foster an inclusive and respectful environment, ground rules were outlined, and participants were encouraged to express their responses openly. The moderator emphasized that there were no right or wrong answers and that differing viewpoints were valuable to the discussion.

Discussions were conducted in Tamil and Odiya, lasting approximately 45 min to 1 h. To maintain rigor, the moderator followed standard practices, concluding each FGD when responses became repetitive, indicating thematic saturation.

Note-taking was carried out by the note-taker. Key quotes that illustrated specific points of view were highlighted and attributed using name of the village and the respondents' code. Responses to major themes from multiple participants were carefully recorded, along with any unique responses expressed only once but deemed significant for the study's objectives. At the conclusion of each FGD, the note-taker summarized the identified themes and shared them with the participants for confirmation. This feedback process ensured accuracy and allowed participants to clarify or expand on their inputs. Based on this summary, the moderator asked follow-up questions to explore important points further or requested examples to elaborate on vague but critical responses, if any.

2.4 Data analysis

Quantitative data were analyzed and presented using descriptive statistics. For the analysis of qualitative data, a traditional method was adopted. During each FGD, the moderator and note-taker summarized the emerging themes at the end of the session to seek confirmation from participants and probe further into any inconsistent or vague responses. Following the FGD, the moderator and note-taker spot-checked the voice recording to ensure its quality and conducted a debriefing session. During the debriefing, they documented the major themes, interpretations. The voice recordings were subsequently transcribed and translated into English for further analysis.

To ensure a comprehensive review, the first two analysts read all transcripts in one sitting to identify the location of specific information and recurring patterns. Both analysts examined the translated transcripts along with the note-taker's reports to derive the final codes and themes. This process involved open discussions between two

analysts. Differing viewpoints were marked for further discussion with the third analyst and subsequently resolved. Separate Excel sheets were maintained for each code and theme. Responses from all FGDs were organized in these sheets, and descriptive quotes that captured the essence of the discussion were highlighted. For subcategories within themes, relevant statements were grouped accordingly. This process continued until all transcripts were thoroughly reviewed.

The analysts then described the findings, supported by notable quotes, and prepared a combined report. Each major theme was presented as a separate section using a narrative style. This report along with Excel file was shared with a senior researcher for verification. Feedback from the senior researchers was incorporated, and the report was revised and finalized. Drawing on qualitative data insights, a comprehensive Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was also conducted at the end (Figure 1).

2.5 Ethical consideration

Ethical approval for the study was obtained from the Institutional Ethics Committee (IEC) of the ICMR-National Institute of Nutrition (NIN). Informed consent was obtained from all participants prior to their recruitment into the study, including consent for the voice recording of FGD sessions.

3 Findings

To contextualize the findings, we provide the basic information about the two study sites. Thiruvallur district in Tamil Nadu has a predominantly urban population (65.2% according to the 2011 Census). Among the rural population, engagement in agricultural activities is relatively low, with many shifting to non-agricultural economic activities. In contrast, Koraput district in Odisha is predominantly rural (84%), with a significant portion of the

| | |
|---|--|
| STRENGTH | WEAKNESSES |
| Active community engagement Collaboration with KVKs to leverage resources and expertise Comprehensive training component Skilled implementation team Insightful exposure visits Enhanced nutritional awareness Improved dietary diversity | Limited seed and sapling varieties Lack of drought-resilient varieties Lack of engagement with participants prior to the distribution of resources Insufficient tailored trainings Overemphasis on seeds and saplings distribution over training (nutrition education) |
| OPPORTUNITIES | THREATS |
| High prevalence of malnutrition The rising trend of overweight and obesity Limited dietary diversity among the population Persistent food insecurity Increasing community recognition of the importance of nutritious diets | Water scarcity Inadequate land Crop protection challenges |

FIGURE 1 Overview of strengths, weaknesses, opportunities, and threats identified in qualitative analysis.

population actively engaged in agriculture. The average landholding of participants also differed considerably between the two sites. In Odisha, participants held an average of 2.7 hectares of land, of which 0.8 hectares had access to year-round irrigation facilities.

3.1 Participation and acceptability

Participation in the program was evaluated based on four key parameters: the duration of involvement in the program; the frequency of attendance in training sessions and related activities, such as meetings and exposure visits over the past year; the uptake of cultivation inputs, including seeds and saplings; and the adoption of cultivation practices and maintenance of nutrition gardens. The evaluation of involvement in the program revealed distinct patterns between the states of Odisha and Tamil Nadu. In Odisha, a significant majority of participants (94%) had sustained their involvement in the program for over 2 years. In contrast, in Tamil Nadu, only 45% of participants had been involved for a comparable duration, while 55% reported participating for 1–2 years. The high level of sustained involvement in Odisha reflects participants' continued interest in the program, signifying its deeper integration and perceived value within the community. This difference in engagement duration is also indicative of the program's relative maturity in Odisha compared to Tamil Nadu.

In terms of attendance in trainings, variation was observed between the two states. Although, the training content was the same across both states, the frequency of attendance in training varied significantly. The average number of training sessions attended in the year preceding the survey was high in Odisha compared to Tamil Nadu. In Tamil Nadu, the vast majority of participants (95%) had attended only one or two training sessions. Conversely, in Odisha, 43% of participants had attended three to five sessions, while 36% had attended more than five sessions. Additionally, over 90% of participants in Odisha received training on the importance of dietary diversity, the cultivation of nutrition-rich local crops, and effective plantation techniques, reflecting the program's emphasis on integrating nutritional education with agricultural practices. The differences in training session attendance also highlight the varying levels of knowledge dissemination across states. In Odisha, participants reported receiving extensive training on vermicomposting and vegetable cultivation techniques.

A participant from Odisha reported, *"the program provided training at the Indian Institute of Soil and Water Conservation and organized an exposure visit to see the nutrition gardens. During the training, we gained knowledge on vermicomposting, and learned techniques for constructing raised beds for crops, as well as cultivating and harvesting vegetables."* – (OD1P3, mother).

Despite these differences, both states demonstrated a very high uptake of the seeds and saplings distributed through the program, achieving 100% uptake. However, we observed a difference in the diversity of seeds and saplings distributed between Tamil Nadu and Odisha. According to participants, the most commonly distributed seeds and saplings in Tamil Nadu were bitter melon, ridge melon, snake melon, and ash melon. In contrast, in Odisha, the most common varieties included bitter melon, pumpkin, brinjal, lady's finger, tomato, moringa, banana, amaranthus, and papaya. During data collection,

we observed more mature nutrition gardens in Odisha, featuring a greater variety of crops compared to those in Tamil Nadu (Table 1).

3.2 The transformative impact on traditional home gardening

The study further explored the program's impact on traditional home gardening practices, which have been a part of the culture in the study areas. In Odisha, the practice of maintaining kitchen gardens was more prevalent compared to Tamil Nadu. Households in Odisha traditionally grew crops that were locally consumed, required minimal maintenance, and were resilient to climatic conditions. These gardens played a vital role in supplementing the supply of vegetables and fruits.

The introduction of the Nutrition Garden program, however, has brought about a transformative shift in these traditional practices. Participants reported that the program's emphasis on training, provision for seeds and saplings, and nutritional education distinguished it from their conventional home gardening methods. The program enabled households to diversify their crop cultivation, thereby integrating nutrition-sensitive practices into their agricultural practices.

In Odisha, participants with prior gardening experience acknowledged the support provided by the program, which included seeds, training, guidance, and exposure visits. In Tamil Nadu, households reported cultivating a wider variety of vegetables and fruits, attributing this diversity to the unique features of the Nutrition Garden program. The program's impact was evident in the reported

TABLE 1 Participation in Nutrition Garden program by the households.

| | Tamil Nadu | Odisha |
|---|------------|------------|
| N (%) | 137 | 138 |
| Years of participation | | |
| <1 year | 0.0 | 5.8 |
| 1–2 years | 55.4 | 6.5 |
| >2 years | 44.6 | 87.7 |
| Benefits received | | |
| Seeds | 100.0 | 100.0 |
| Training | 91.0 | 100.0 |
| Financial assistance | 2.2 | 1.4 |
| Training sessions attended | | |
| 0 | 0.0 | 12.3 |
| 1–2 | 95.3 | 8.7 |
| 3–5 | 4.7 | 42.8 |
| >5 | 0 | 36.2 |
| Topic discussed in the training | | |
| Importance of having diet diversity | 84.0 | 97.1 |
| Nutri-rich local crops | 85.0 | 97.1 |
| Plantation techniques | 89.0 | 92.8 |
| Challenges in implementing the program | | |
| Yes | 43.7 | 47.4 |

improvement in diversity of crops cultivated, with participants gaining access to previously inaccessible vegetables and fruits.

Participants' from both the states reported an increase in the diversity of vegetables cultivated within their farms or backyards as a direct result of their participation in the program. For instance, a participant from Tamil Nadu, who previously focused on ornamental plants and Moringa, expanded her garden to include six different vegetable varieties after receiving training and seeds from the implementing agency.

"Before joining the program, I was cultivating only ornamental flowering plants and moringa. However, after the KVK staff visited our village, they provided training and distributed a seed package containing six different varieties of vegetables (brinjal, bottle gourd, snake gourd, ridge gourd, bitter gourd, and hyacinth bean). Now, we cultivate all these varieties in our garden." – (TN4 P1, mother).

Overall, the Nutrition Garden program has played a significant role in transforming the conventional approach to kitchen gardening, which previously focused primarily on mitigating market stress (such as price rise) by growing commonly consumed vegetables. The new program, however, places a greater emphasis on nutrition, not only by expanding the variety of food available but also by strengthening nutrition-related education.

3.3 Perceived impacts

The perceived impact of the program on nutritional knowledge, dietary diversity, and nutritional outcomes varied significantly between Tamil Nadu and Odisha. In Tamil Nadu, over 90% of participants acknowledged the training and the provision of seeds by the implementing agency as both beneficial and useful for cultivation. Furthermore, 75% of participants reported that they are now better aware of nutrition-related topics, including the importance of dietary diversity, and the specific fruits and vegetables beneficial for women and children. However, only 29% of households reported an actual improvement in vegetable and fruit intake attributable to the program, with a similar percentage noting an increase in dietary diversity. This disparity suggests that, while the program has been effective in improving nutritional awareness, its impact on actual dietary practices has been limited in Tamil Nadu.

In contrast, participants in Odisha reported greater benefits from the Nutrition Garden program. Specifically, 97% of respondents reported improvement in food intake and dietary diversity as a result of the program, with a similar percentage reporting enhanced nutrition and health. Women from participating households reported a positive change in dietary diversity for themselves and their children following the implementation of the program. They noted that the program enabled them to grow new varieties of vegetables, roots, and fruits, such as moringa, papaya, yam, and sweet potatoes, which were previously uncommon in their villages. Additionally, the women reported that the program encouraged the cultivation of green leafy vegetables, which have since become a regular part of their diet, alongside other vegetables and seasonal fruits.

A participant from Odisha reported that *"the volunteers from the implementing agency encouraged them to cultivate their own vegetables for a healthy diet. The provision of seeds by the agency has enabled them to cultivate green leafy vegetables and thereby improve their consumption. Additionally, they now include other vegetables in their*

diet, enjoy non-vegetarian meals twice a week, and occasionally consume seasonal fruits harvested from their own nutrition garden." – (OD1P8, mother).

This suggests that the program's impact on dietary practices was more significant in Odisha, likely due to the provision of more comprehensive training, the distribution of a wider variety of seeds and saplings, and the handholding of the implementing agency. Participants in Odisha have started experiencing the benefits of the program, such as improved dietary diversity, as they are now able to produce and consume a wider variety of vegetable from their own gardens. In contrast, participants in Tamil Nadu, while aware of the importance of dietary diversity, have seen limited improvement, with only a few households increasing their fruit and vegetable intake using their own product from nutrition gardens.

3.4 Sustainability and scalability

The sustainability of the Nutrition Garden program was assessed by examining participants' perceptions of their ability to maintain the gardens without the ongoing support (provision for seeds and saplings, and trainings) of the implementing agency. In Tamil Nadu, 74% of participating households expressed confidence in their ability to sustain the gardens independently, while in Odisha, 94% of households shared this view. This high level of confidence suggests that the program has empowered participants to continue the initiative on their own (Table 2).

Participants in Tamil Nadu (44%) and Odisha (47%) reported various challenges that hinder the success of nutrition gardens. In Odisha, key issues included water scarcity, small and fragmented landholdings, and crop damage caused by animals. In Tamil Nadu,

TABLE 2 Participants' perception about Nutrition Garden program (%).

| Perception of participants | Tamil Nadu | Odisha |
|---|------------|--------|
| N | 137 | 138 |
| Trainings provided were useful | 93.0 | 96.4 |
| Seeds provided were useful | 97.0 | 97.1 |
| Participation in the program was beneficial | 94.0 | 97.1 |
| Seeds/staples given were easy to cultivate and maintain | 93.0 | 97.1 |
| Improvement in the nutrition-related knowledge | 75.0 | 95.7 |
| Improvement in food intake due to the program | 29.0 | 97.1 |
| Improvement in diet diversity due to the program | 28.0 | 97.1 |
| Improvement in nutrition and health due to the program | 29.2 | 97.1 |
| The Nutri-garden can be sustained without the support of agencies | 73.7 | 94.2 |

similar challenges were reported, with additional concerns about unpredictable weather and pest infestations.

A participant from Tamil Nadu reported that *“cultivating and maintaining plants is not a challenging task, as they are already growing amla, guava, and custard apple. She expressed her readiness to integrate the new seeds into her existing cultivation but preferred not to grow creepers as they require more space. Instead, she suggested that seeds for plants such as lady’s finger, tomato, chili, and brinjal would be more convenient, as these do not demand as much space.”* – (TN3P2, mother).

Highlighting the challenge of limited landholdings, one participant shared, *“I cultivated hyacinth beans and brinjal, but I could not plant creepers due to the limited space we have. So, I gave them to my brother.”* Another participant discussed pest infestations, saying, *“all my hyacinth bean saplings grown, but they were completely ruined by insects.”*

Water scarcity emerged as a significant challenge in both states, with participants reporting difficulties in maintaining their gardens during the dry season. Crop damage caused by animals was also a common issue, with several participants suggesting the provision for fencing as a potential solution. One participant explained *“If we cultivate anything, nothing will grow. Here in our village, pigs are the major problem; they spoil everything.”*

The widespread challenges reported regarding the long-term sustainability of the gardens—such as water scarcity, limited land availability, and crop protection issues from pests and diseases—have been partially addressed in Odisha. Participants in Odisha received training on preparing biofertilizers and pesticides, and enhancing this training could further equip households tackle these issues. To address the limited land availability for growing nutrition gardens, participants in Odisha identified larger unused plots within the village and collectively cultivated nutrition gardens. However, water scarcity remains a larger structural issue that requires the intervention from local governments. In contrast, all challenges reported by the participants in Tamil Nadu, including crop destruction by free-roaming pigs, remain unaddressed.

These challenges underscore the need to incorporate them into program design and to develop location-specific strategies to tackle unique local issues. If left unresolved, these barriers could undermine the program’s long-term success. Therefore, it is essential to implement measures that address these threats and provide participants with the support needed to overcome these obstacles. While the Nutrition Garden program has been successful in promoting nutrition-sensitive agricultural practices and enhancing nutrition education, its long-term impact hinges on effectively addressing these structural and social challenges.

4 Discussion

This study contributes to the growing body of research on Nutrition Garden programs by exploring participants’ perspectives on their design, implementation, and outcomes. The findings underscore the success of Nutri-Garden interventions in integrating nutrition-sensitive agricultural practices into traditional gardening, though their impact varied across states. Odisha emerged as a model for strong community engagement, frequent and diverse training sessions, a wider variety of crops, improved access to food, increased consumption of diverse produce, and better-perceived

nutrition and health outcomes. The program’s strengths included active community involvement, a comprehensive training approach supported by skilled volunteers, and exposure visits. However, certain weaknesses were evident, particularly in Tamil Nadu, where limited seed and sapling variety, inadequate alignment with community needs, and an emphasis on distribution of seed and sapling over training posed challenges. Broader structural barriers, such as small landholdings, lack of irrigation facilities, and crop protection from animals, further constrained the program’s success. Despite these limitations, the intervention shows considerable potential for scaling up, as communities value its provision of nutritious and organic food options.

Consistent with previous studies (Ritter et al., 2024; Wilcox et al., 2024; Prost et al., 2022; Nielsen et al., 2018; Laurie et al., 2017; Shah et al., 2023; Kuma et al., 2023), our findings also highlight the value of nutrition garden interventions as tools for addressing malnutrition in vulnerable populations. Several studies including ours found a positive relationship between crop diversity and dietary quality (Ritter et al., 2024; Shah et al., 2023; Ruel et al., 2018; Depenbusch et al., 2022); however, the link between crop diversity and measurable improvements in nutritional status remains weaker (Prost et al., 2022; Kumar et al., 2023). Achieving sustained nutritional outcomes often requires long-term efforts focused on behavioral change, community empowerment, strengthening local structures, and addressing the challenges (Di Prima et al., 2022).

Although nutrition garden interventions can facilitate multidimensional improvements in women empowerment, nutrition education, diet diversity, and nutrition and health outcomes among vulnerable populations (Palar et al., 2019), their long-term success depends on several critical factors. Extended implementation periods, comprehensive training and monitoring, and sustained partner commitment are critical for ensuring tangible, sustainable nutritional outcomes (Galhena et al., 2013; WVC, 2016; Olney et al., 2015; Blakstad et al., 2022). The success of the program also depends on the flexibility of its design to account for the dynamic needs of target communities, as highlighted by previous studies (Di Prima et al., 2022; Hotz et al., 2012; Haselow et al., 2016; Talukder et al., 2000). Our study also highlights the importance of context-specific adaptations. For instance, in Tamil Nadu, the promotion of creeper varieties conflicted with participants’ constraints on land availability, leading to lower acceptance of the program, and lower crop and dietary diversity compared to Odisha. The co-creation of program designs and training modules, emphasizing an understanding of participants’ needs and constraints, will enhance the effectiveness of the intervention (Kokkorou et al., 2025; Carins and Bogomolova, 2021; Wargers et al., 2024; Russell et al., 2024). A fixed design may not work in all contexts. For instance, in Tamil Nadu, where the population is more urbanized and less engaged in agriculture, a separate strategy is needed to ensure better participation and achieve success.

Furthermore, while nutrition gardens and education programs focus on women, their success in improving their diets depends on reforming social norms around intra-household food distribution, and gender. Traditional intra-household food-sharing practices often favor men, limiting the dietary improvements for women and children despite adequate access to food. To ensure equitable benefits, the program must adopt a family-centric approach that acknowledges women’s decision-making power within households and involves other family members, such as husbands and in-laws (Prost et al.,

2022). These dimensions also need to be incorporated into the training modules.

This study highlights the varying impacts of the same program across two regions in India with distinct socio-economic and cultural characteristics. While the program demonstrated strengths like active community involvement, and comprehensive training, its success is hindered by weaknesses such as a limited variety of seeds and saplings, inadequate alignment with community needs, and an overemphasis on seed distribution—issues more prominent in Tamil Nadu. We learned that monitoring and taking participant feedback are crucial factors. By understanding challenges, the implementing agency in Odisha could address challenges like fragmented land, water scarcity, and crop protection by facilitating collective cultivation on irrigated village land, and providing training on biofertilizer and pesticide formulation. In Tamil Nadu, however, such feedback mechanisms and interventions were absent. These findings underscore the need for a transformative approach to program design and implementation, emphasizing continuous monitoring and adaptive strategies at each stage.

5 Conclusion

In conclusion, nutrition garden interventions show great promise for improving nutrition and health outcomes among vulnerable populations. However, their effectiveness relies on context-sensitive designing, implementation, sustained engagement, and addressing structural barriers (lack of irrigation facilities, etc.). The findings from this study highlight the program's relevance and acceptability. Nonetheless, the scalability and success of such programs depend on a thorough understanding of community needs and social and structural barriers through the design and implementation stages.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AJ: Conceptualization, Data curation, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. SC: Conceptualization, Data curation, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. RS: Investigation, Methodology, Writing – review & editing. HP: Data curation, Investigation, Writing – review & editing. PS: Writing – original draft. IM: Writing – review & editing. AL: Writing – review & editing, Methodology, Supervision. GH: Methodology, Writing – review & editing. NA: Supervision, Writing – review & editing. SG:

Conceptualization, Funding acquisition, Investigation, Methodology, Supervision, Validation, Writing – review & editing.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by the Biotechnology Industry Research Assistance Council (BIRAC). BIRAC provided financial assistance for data collection and community engagement activities. The funder had no role in study design, data analysis, result interpretation, or manuscript preparation.

Acknowledgments

The authors gratefully acknowledge the Biotechnology Industry Research Assistance Council (BIRAC) for funding this study. We also thank the Krishi Vigyan Kendra's (KVKs) at the study sites and the M. S. Swaminathan Research Foundation (MSSRF) for facilitating the study. Special thanks are due to the project staff and study participants for their time and valuable contributions. We also express our gratitude to the Nutrition Society of India (NSI) for selecting and awarding the initial version of this paper with the 1st Prize for oral presentation under the Young Scientist Award category at their 55th annual conference held in Hyderabad, India. We are grateful to Dr. Rajiv Bahl, Director-General, ICMR and Dr. Hemalatha, Director, National Institute of Nutrition (NIN) for encouragement in carrying out the study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2025.1502711/full#supplementary-material>

References

- Angeles-Agdeppa, I., Monville-Oro, E., Gonsalves, J. F., and Capanzana, M. V. (2019). Integrated school based nutrition programme improved the knowledge of mother and schoolchildren. *Matern. Child Nutr.* 15:e12794. doi: 10.1111/mcn.12794
- Baliki, G., Weiffen, D., Moiles, G., and Brück, T. (2023). Home garden interventions in crisis and emergency settings. *Front. Sustain. Food Syst* 7:1138558. doi: 10.3389/fsufs.2023.1138558
- Bamji, M. S., Murty, P. V. V. S., and Sudhir, P. D. (2021). Nutritionally sensitive agriculture—an approach to reducing hidden hunger. *Eur. J. Clin. Nutr.* 75, 1001–1009. doi: 10.1038/s41430-020-00760-x
- Bamji, M. S., Murty, P., and Sudhir, K. P. D. (2022). Promotion of food and nutrition security through farm technologies and Behavioural change communication, targeting women. *Natl. Acad. Sci. Lett.* 45, 281–286. doi: 10.1007/s40009-022-01117-7
- Bhullar, A. (2021). “Household gardens: a promising approach to enhance food security and sustainability” in Covid-19 pandemic and economic development: Emerging public policy lessons for Indian Punjab. eds. S. Singh, L. Singh and K. Vatta (Singapore: Springer Singapore), 61–67.
- Bhutta, Z. A., Ahmed, T., Black, R. E., Cousens, S., Dewey, K., Giugliani, E., et al. (2008). What works? Interventions for maternal and child undernutrition and survival. *Lancet (London, England)*. 371, 417–440. doi: 10.1016/S1014-6736(07)61693-6
- Blakstad, M. M., Moshia, D., Bliznashka, L., Bellows, A. L., Canavan, C. R., Yussuf, M. H., et al. (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. doi: 10.1016/j.foodpol.2022.102248
- Bucher, A., and Bucher, R. (2017). Working with Santal villagers, West Bengal, India: Moringa and kitchen gardens to combat malnutrition, 2012–2017. *World Rev. Nutr. Diet.* 118, 77–83. doi: 10.1159/000484343
- Bushamuka, V. N., de Pee, S., Talukder, A., Kiess, L., Panagides, D., Taher, A., et al. (2005). Impact of a homestead gardening program on household food security and empowerment of women in Bangladesh. *Food Nutr. Bull.* 26, 17–25. doi: 10.1177/156482650502600102
- Carins, J., and Bogomolova, S. (2021). Co-designing a community-wide approach to encouraging healthier food choices. *Appetite* 162:105167. doi: 10.1016/j.appet.2021.105167
- Choudhury, S., Shankar, B., Aleksandrowicz, L., Tak, M., Green, R., Harris, F., et al. (2020). What underlies inadequate and unequal fruit and vegetable consumption in India? An exploratory analysis. *Glob Food Sec* 24:100332. doi: 10.1016/j.gfs.2019.100332
- Deppenbusch, L., Schreinemachers, P., Brown, S., and Roothaert, R. (2022). Impact and distributional effects of a home garden and nutrition intervention in Cambodia. *Food Secur.* 14, 865–881. doi: 10.1007/s12571-021-01235-y
- Di Prima, S., Wright, E. P., Sharma, I. K., Syurina, E., and Broerse, J. E. W. (2022). Implementation and scale-up of nutrition-sensitive agriculture in low- and middle-income countries: a systematic review of what works, what doesn't work and why. *Glob. Food Sec.* 32:100595. doi: 10.1016/j.gfs.2021.100595
- FAO. Strengthening indigenous food systems is key to achieving a zero-hunger world Rome (2018). Available at: <https://www.fao.org/newsroom/detail/Strengthening-indigenous-food-systems-is-key-to-achieving-a-zero-hunger-world/en>.
- FAO, IFAD, UNICEF, WFP and WHO. (2024). The state of food security and nutrition in the world 2024 – Financing to end hunger, food insecurity and malnutrition in all its forms. Rome: FAO, IFAD, UNICEF, WFP and WHO. Available at: <https://openknowledge.fao.org/server/api/core/bitstreams/d5be2ffc-f191-411c-9fee-bb737411576d/content>
- FAO (2014). Nutrition, education and awareness raising for the right to adequate food. Rome: FAO.
- Ferdous, Z., Datta, A., Anal, A. K., Anwar, M., and Khan, A. S. M. M. R. (2016). Development of home garden model for year round production and consumption for improving resource-poor household food security in Bangladesh. *NJAS-Wageningen journal of. Life Sci.* 78, 103–110. doi: 10.1016/j.njas.2016.05.006
- Galhena, D. H., Freed, R., and Maredia, K. M. (2013). Home gardens: a promising approach to enhance household food security and wellbeing. *Agric. Food Secur.* 2:8. doi: 10.1186/2048-7010-2-8
- Garrity, K., Krzyzanowski Guerra, K., Hart, H., Al-Muhanna, K., Kunkler, E. C., Braun, A., et al. (2024). Local food system approaches to address food and nutrition security among low-income populations: a systematic review. *Adv. Nutr.* 15:100156:100156. doi: 10.1016/j.advnut.2023.100156
- Guell, C., Brown, C. R., Iese, V., Navunicagi, O., Wairiu, M., and Unwin, N. (2021). “We used to get food from the garden.” understanding changing practices of local food production and consumption in small island states. *Soc. Sci. Med.* 284:114214. doi: 10.1016/j.socscimed.2021.114214
- Haselow, N. J., Stormer, A., and Pries, A. (2016). Evidence-based evolution of an integrated nutrition-focused agriculture approach to address the underlying determinants of stunting. *Matern. Child Nutr.* 12, 155–168. doi: 10.1111/mcn.12260
- Hotz, C., Loechl, C., de Brauw, A., Eozenou, P., Gilligan, D., Moursi, M., et al. (2012). A large-scale intervention to introduce orange sweet potato in rural Mozambique increases vitamin A intakes among children and women. *Br. J. Nutr.* 108, 163–176. doi: 10.1017/S0007114511005174
- Hume, C., Grieger, J. A., Kalamkarian, A., D'Onise, K., and Smithers, L. G. (2022). Community gardens and their effects on diet, health, psychosocial and community outcomes: a systematic review. *BMC Public Health* 22:1247. doi: 10.1186/s12889-022-13591-1
- IFAD. (2015). How to do—Integrated homestead food production (IHFP). IFAD Available at: <https://www.ifad.org/documents/48415603/49831320/How+to+do+note+-+Integrated+homestead+food+production+%28IHFP%29.pdf/2504a2c8-45cb-0b14-6597-3e2350c1df80?t=1726644362255>
- IGSSS (2021). Manual on nutrition garden. New Delhi: Indo-Global Social Service Society. Available at: <https://igsss.org/wp-content/uploads/2022/06/Manual-on-Nutrition-Garden.pdf>
- IIPS, ICF (2021). National Family Health Survey –5. Mumbai: International Institute of Population Sciences.
- Kokkorou, M., Spinelli, S., Dinnella, C., Pierguidi, L., Wollgast, J., Maragkoudakis, P., et al. (2025). Co-creating innovative and accepted legume-based dishes for school canteens with adolescents in a low socioeconomic area. *Food Qual. Prefer.* 123:105343. doi: 10.1016/j.foodqual.2024.105343
- Konapur, A., Gavaravarapu, S. M., and Nair, K. M. (2022). The 5 A's approach for contextual assessment of food environment. *J. Nutr. Educ. Behav.* 54, 621–635. doi: 10.1016/j.jneb.2022.02.017
- Kuma, M. N., Tamiru, D., and Belachew, T. (2023). Effects of nutrition education and home gardening interventions on fetomaternal outcomes among pregnant women in Jimma zone, Southwest Ethiopia: a cluster randomized controlled trial. *PLoS One* 18:e0288150. doi: 10.1371/journal.pone.0288150
- Kumar, A., Sethi, V., Wagt, A., Parhi, R. N., Bhattacharjee, S., Unisa, S., et al. (2023). Evaluation of impact of engaging federations of women groups to improve women's nutrition interventions- before, during and after pregnancy in social and economically backward geographies: evidence from three eastern Indian states. *PLoS One* 18:e0291866. doi: 10.1371/journal.pone.0291866
- Lal, R. (2020). Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. *Food Secur.* 12, 871–876. doi: 10.1007/s12571-020-01058-3
- Laurie, S. M., Faber, M., and Maduna, M. M. (2017). Assessment of food gardens as nutrition tool in primary schools in South Africa. *South Afr. J. Clin. Nutri.* 30, 80–86. doi: 10.1080/16070658.2017.1271609
- MoHFW, UNICEF, Population Council. (2019). Comprehensive National Nutrition Survey (CNNS) National Report. New Delhi: Ministry of Health & Family Welfare and UNICEF Nutrition Section. Available at: <https://www.unicef.org/india/media/2646/file/CNNS-report.pdf>
- Nair, M. K., Augustine, L. F., and Konapur, A. (2015). Food-based interventions to modify diet quality and diversity to address multiple micronutrient deficiency. *Front. Public Health* 3:100156. doi: 10.3389/fpubh.2015.00277
- Nielsen, J. N., Olney, D. K., Ouedraogo, M., Pedehombga, A., Rouamba, H., and Yago-Wienne, F. (2018). Process evaluation improves delivery of a nutrition-sensitive agriculture programme in Burkina Faso. *Matern Child Nutr* 14:e12573. doi: 10.1111/mcn.12573
- Niñez, V. (1987). Household gardens: theoretical and policy considerations. *J. Agri. Syst.* 23, 167–186. doi: 10.1016/0308-521X(87)90064-3
- Olney, D. K., Pedehombga, A., Ruel, M. T., and Dillon, A. (2015). A 2-year integrated agriculture and nutrition and health behavior change communication program targeted to women in Burkina Faso reduces Anemia, wasting, and diarrhea in children 3–12.9 months of age at baseline: a cluster-randomized controlled trial 1, 2, 3. *J. Nutr.* 145, 1317–1324. doi: 10.3945/jn.114.203539
- Osei, A., Pandey, P., Nielsen, J., Pries, A., Spiro, D., Davis, D., et al. (2017). 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 Nutr. Bull.* 38, 49–64. doi: 10.1177/0379572116676427
- Palar, K., Lemus Hufstедler, E., Hernandez, K., Chang, A., Ferguson, L., Lozano, R., et al. (2019). Nutrition and health improvements after participation in an urban home garden program. *J. Nutr. Educ. Behav.* 51, 1037–1046. doi: 10.1016/j.jneb.2019.06.028
- Pem, D., and Jeewon, R. (2015). Fruit and vegetable intake: benefits and Progress of nutrition education interventions-narrative review article. *Iran. J. Public Health* 44, 1309–1321.
- Piscopo, S. (2019). “Nutrition education” in Encyclopedia of food security and sustainability. eds. P. Ferranti, E. M. Berry and J. R. Anderson (Oxford: Elsevier), 378–384.
- Prost, A., Harris-Fry, H., Mohanty, S., Parida, M., Krishnan, S., Fivian, E., et al. (2022). Understanding the effects of nutrition-sensitive agriculture interventions with participatory videos and women's group meetings on maternal and child nutrition in

- rural Odisha, India: a mixed-methods process evaluation. *Matern. Child Nutr.* 18:e13398. doi: 10.1111/mcn.13398
- Ritter, T., Mockshell, J., Garrett, J., Ogutu, S., and Asante-Addo, C. (2024). A process evaluation of a home garden intervention. *Agric. Food Secur.* 13:44. doi: 10.1186/s40066-024-00499-9
- Ruel, M. T., Quisumbing, A. R., and Balagamwala, M. (2018). Nutrition-sensitive agriculture: what have we learned so far? *Glob. Food Sec.* 17, 128–153. doi: 10.1016/j.gfs.2018.01.002
- Russell, R. D., Black, L. J., Purdue, J., Daly, A., and Begley, A. (2024). A collaborative approach to designing an online nutrition education program for people with multiple sclerosis. *Disabil. Rehabil.* 46, 947–956. doi: 10.1080/09638288.2023.2186499
- Shah, N., Zaheer, S., Safdar, N. F., Turk, T., and Hashmi, S. (2023). Women's awareness, knowledge, attitudes, and behaviours towards nutrition and health in Pakistan: evaluation of kitchen gardens nutrition program. *PLoS One* 18:e0291245. doi: 10.1371/journal.pone.0291245
- Shankar, B., Agrawal, S., Beaudreault, A. R., Avula, L., Martorell, R., Osendarp, S., et al. (2017). Dietary and nutritional change in India: implications for strategies, policies, and interventions. *Ann. N. Y. Acad. Sci.* 1395, 49–59. doi: 10.1111/nyas.13324
- Sharma, R., Mina, U., and Kumar, B. M. (2022). Homegarden agroforestry systems in achievement of sustainable development goals. A review. *Agron. Sustain. Dev.* 42:44. doi: 10.1007/s13593-022-00781-9
- Singh, A., Dhasmana, A., Bandhu, A., Kapoor, R., Baalashubramanian, S., and Ghosh-Jerath, S. (2023). Contribution of natural food environments to nutritional intake and biomarker status: insights from the women of indigenous santhal communities of Jharkhand, India. *BMC Nutrition.* 9:20. doi: 10.1186/s40795-023-00669-1
- Tak, M., Shankar, B., and Kadiyala, S. (2019). Dietary transition in India: temporal and regional trends, 1993 to 2012. *Food Nutr. Bull.* 40, 254–270. doi: 10.1177/0379572119833856
- Talukder, A., Kiess, L., Huq, N., de Pee, S., Darnton-Hill, I., and Bloem, M. W. (2000). Increasing the production and consumption of vitamin A-rich fruits and vegetables: lessons learned in taking the Bangladesh homestead gardening programme to a national scale. *Food Nutr. Bull.* 21, 165–172. doi: 10.1177/156482650002100210
- Tontisirin, K., Nantel, G., and Bhattacharjee, L. (2002). Food-based strategies to meet the challenges of micronutrient malnutrition in the developing world. *Proc. Nutr. Soc.* 61, 243–250. doi: 10.1079/PNS2002155
- Unisa, S., Saraswat, A., Bhanot, A., Jaleel, A., Parhi, R. N., Bhattacharjee, S., et al. (2021). Predictors of the diets consumed by adolescent girls, pregnant women and mothers with children under age two years in rural eastern India. *J. Biosoc. Sci.* 53, 663–682. doi: 10.1017/S0021932020000462
- Wargers, A., Polychronakis, K., Nieboer, D., Raat, H., and Jansen, W. (2024). Co-creation and implementation of a healthy lunch at Dutch primary schools in disadvantaged neighbourhoods: design of a cluster randomised cross-over effectiveness study. *BMJ Open* 14:e083534. doi: 10.1136/bmjopen-2023-083534
- Wendt, A. S., Sparling, T. M., Waid, J. L., Mueller, A. A., and Gabrysch, S. (2019). Food and agricultural approaches to reducing malnutrition (FAARM): protocol for a cluster-randomised controlled trial to evaluate the impact of a homestead food production programme on undernutrition in rural Bangladesh. *BMJ Open* 9:e031037. doi: 10.1136/bmjopen-2019-031037
- Wilcox, H., Bishop, S., Francis, B., Lombard, K., Beresford, S. A. A., and Ornelas, I. J. (2024). Process evaluation of the Yéego! Program to increase healthy eating and gardening among American Indian elementary school children. *BMC Public Health* 24:232. doi: 10.1186/s12889-024-17689-6
- WVC (2016). The world vegetable center approach to household gardening for nutrition. Taiwan: World Vegetable Center Shanhua.