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RECEIVED 30 October 2025

REVISED 18 January 2026

ACCEPTED 23 January 2026

PUBLISHED 17 February 2026

CITATION

Sharma V, Rastogi A, Kohli S, Dhasmana A and Ghosh-Jerath S (2026) Contribution of food environment to food security and dietary diversity in rural Andhra Pradesh, India: an exploratory study to inform a food systems intervention.

Front. Sustain. Food Syst. 10:1735546.
doi: 10.3389/fsufs.2026.1735546

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Contribution of food environment to food security and dietary diversity in rural Andhra Pradesh, India: an exploratory study to inform a food systems intervention

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Background: India is experiencing a growing burden of overnutrition, with nearly one-quarter of adults being overweight or obese, alongside a rising burden of non-communicable diseases and persistent undernutrition. Food environment influences food choices, diet quality, and nutritional status of a community. Urbanization and lifestyle changes are transforming rural food environments, contributing to both malnutrition and rising non-communicable diseases. In India, there is limited understanding of how public food procurement programs (PFPPs) affect household food access, diet quality, and food security, and this evidence is needed to design nutrition-focused interventions using PFPPs. This study assessed contribution of food environment to food security and dietary diversity among rural communities in Andhra Pradesh, India.

Methods: A cross-sectional study was conducted in 16 randomly selected villages from four blocks in Srikakulam district, Andhra Pradesh. Data were collected in 328 households (HHs) on socio-economic profile, HH food environment profile, HH food security status ($n = 320$), and dietary diversity ($n = 323$) of adult women of reproductive age (18–49 years). Food Insecurity Experience Scale was used to assess HH food security. A digital tool developed based on Minimum Dietary Diversity for Women was used to assess dietary diversity (24-hour recall). Simple and multiple variable mixed effect linear/binary, logistic/ordinal logistic regressions were used to check the associations between the outcomes (food insecurity and dietary diversity) and key independent variables.

Results: The community majorly accessed food from local markets (99%), government food programs (98%), and farmland (69%). Only 40% HHs experienced food security. The mean Dietary Diversity Score (DDS) for women was 4.39 ± 1.27 . Analysis revealed that women from mild, moderate, and severe food-insecure households had 0.04 units, 0.38 units, and 0.72 units lower DDS, respectively, compared to those from food-secure households ($p = 0.042$). Access to food from a kitchen garden was associated with an increase of 0.68 units in DDS ($p < 0.05$).

Conclusion: Nearly half of households faced mild to moderate food insecurity, over half of women had low dietary diversity, and most families accessed food from local markets, PFPPs, and farmland. Strengthening local food systems and their integration into government food supplementation programs can be vital in addressing these challenges.

KEYWORDS

dietary diversity, food environment, food security, food systems, Indian adults, policy recommendations, rural

1 Introduction

Food systems play a key role in informing dietary patterns and nutritional outcomes of a population. It includes all components and activities involved in the production, processing, distribution, preparation, and consumption of food (HLPE, 2017). It also covers the effects of these processes on society, economy, and environmental impact. When people interact with the food system to make decisions regarding food purchase, preparation, and consumption, they are referring to their food environment (HLPE, 2017; Swinburn et al., 2014). The food environment influences what people access and eat, food choices, preferences, and diet quality of a community, which has a direct impact on the nutritional status (Global Panel on Agriculture, Nutrition, 2017). It has the potential to contextualize food-based interventions for a specific population group, thereby ensuring their food and nutrition security (HLPE, 2017).

In recent decades, global food systems have undergone significant shifts with changing consumption patterns and diets among populations (Popkin, 2017). These changes, known as nutrition transition, reflect evolving dietary habits and nutrient intake as societies adopt modern lifestyles due to economic and social development (Popkin, 2004). Some of the key drivers impacting food systems are urbanization, lifestyle changes, rising income, population growth, climate change, and globalization of food trade (Béné et al., 2019). Most of the developed and industrialized countries globally have transitioned to the stage where consumption of ultra-processed foods is high, and physical activity has reduced (Popkin and Ng, 2022). Such transitions are now occurring at an even faster rate in many low and middle-income countries (LMICs). This is leading to high rates of diet-related non-communicable diseases (NCDs), such as overweight and obesity (Popkin et al., 2020). In countries like India, Indonesia, and those in sub-Saharan Africa, this is happening parallelly while countries are still struggling to address the burden of undernutrition. Thus, facing significant levels of double burden of malnutrition (DBM) (Popkin et al., 2020; Reardon et al., 2021).

Food security is defined as a condition when everyone at the household level always has access to enough safe and nutritious food that meets their dietary needs to stay healthy, and also aligns with their preferences (FAO, 2008; FAO, 2018a). Approximately 2.4 billion people globally encountered moderate to severe food insecurity in 2022, and one in 10 people face hunger (United Nations, 2024). Higher food insecurity has been associated with lower dietary diversity among population groups (Langer et al., 2024; Ganpule et al., 2023; Nair and Muley, 2024; Vuong et al., 2023). Both food security and dietary diversity are essential elements for achieving sustainable development goals related to health, well-being, and poverty reduction (United Nations, 2024).

Recent findings indicate changing food consumption patterns in India. Adults in rural areas consume diets that are more heavily based on cereals and millets than those in urban areas. On the contrary, their intake of pulses, milk and milk products, eggs and flesh food, vegetables, and fruits is lower compared to the urban population (Hemalatha et al., 2023). In both rural and urban areas, processed

food makes up nearly 10% of the average total caloric intake (Sharma et al., 2020). The household consumption expenditure survey (2022–23) of India has also highlighted a monthly per capita expenditure (MPCE) of 46.38% on food items by rural population of which 9.62% (a fifth) is spent on beverages, refreshments, and processed food (including purchased cooked meals) (MOSPI, 2023). This reflects a transition of food environment with the infiltration of poor-quality energy-dense, high-fat, salt, and sugar packaged processed foods. It is a potential risk factor for exacerbating the DBM, which has become a major public health challenge. The DBM is evident from the National Family and Health Survey (ICF and IIPS, 2021), which is showing increasing prevalence of overweight in children (< 5 years) along with high prevalence of anaemia, underweight and stunting. India continues to face unacceptably high levels of malnutrition among children under five, with 35.5% stunted, 19.3% wasted, 32.1% underweight, and 3.4% overweight. Among adults, 22.9% of men and 24.0% of women are overweight or obese (BMI \geq 25.0 kg/m²). In addition, the burden of NCDs (such as high blood sugar and hypertension), along with risk-factors (such as waist-to-hip ratio) and presence of anemia and low BMI is rising among adults in both urban as well as rural areas (ICF and IIPS, 2021). In Andhra Pradesh, 31% of children under five are stunted, 16% are wasted, and 30% are underweight. About half of women (49%) and men (53%) have a waist-to-hip ratio that puts them at high risk of metabolic problems (ICF and IIPS, 2021).

Given this present situation in India, there is a need to prioritize and implement 'double-duty actions' that address DBM (WHO, 2017), particularly in rural and urban economically vulnerable households, aiming to reduce undernutrition while simultaneously tackling the rising prevalence of overweight and obesity (Nguyen et al., 2021). Public food procurement programs (PFPPs) are crucial entry points in this regard for encouraging people to adopt healthy diets and promoting the development of a more sustainable food systems (FAO, 2021a). PFPPs aim to ensure food and nutrition security among their recipients, especially the vulnerable population groups. They can shape food norms, influence consumption and production, and provide social, economic, and environmental benefits (Swensson et al., 2021). Also, local, regional, and national governments can tailor these programs to their policy objectives, priorities, and sustainability goals. These programs have the potential to transform the food environment, promote healthy dietary practices, provided the policies around them are tweaked to address DBM. There is a need to generate evidence to understand food environments in LMICs and their role in food security and dietary diversity in rural communities. These insights will help inform policies for PFPPs and ensure they address all forms of malnutrition. In India, PFPPs operate within complex food systems, i.e., these are implemented through multiple coordinated policies, government departments, institutions, and delivery mechanisms working together. Yet, there is insufficient context-specific understanding of how they influence food access, diet quality, and food security outcomes at the household level. This evidence can help in designing interventions that aim to utilize PFPPs as a platform for improving nutrition outcomes.

The present research is part of a larger study that aims to develop a sustainable food systems intervention, focusing on PFPPs, to enhance dietary diversity and food security, addressing the risk of malnutrition and diet-related NCDs, and reducing negative environmental impact. Development of such an intervention requires familiarization with the existing food environment, diet quality, and food security situation of the target population. The present paper presents a situational analysis of rural communities in Andhra Pradesh to assess their food environment, food security, and dietary quality among households accessing PFPPs in Andhra Pradesh, India. By generating context-specific evidence, this study is likely to inform policies around PFPPs and contextualize them to the current food environment to better address dietary diversity and food security in the study communities.

2 Materials and methods

This paper reports findings of a household survey conducted in the study population, that explored the community's perception or lived experiences of their food environment, their food security status, and assessed the diversity of diet consumed by women in the reproductive age group present in the household during the survey.

2.1 Study design and locale

The present cross-sectional study was conducted in selected villages from rural blocks/mandals (a local administrative unit within a district) of Srikakulam district in Andhra Pradesh, India in April 2024. Srikakulam has a predominantly agrarian food environment, with majority of the households dependent on agriculture. While paddy is the main crop, the district also produces wide variety of millets, horse gram, red gram and a variety of vegetables and fruits. Pisciculture is commonly practiced in wetlands which also provides ecosystem services including water for irrigation and fish culture (Sebastian et al., 2012). Despite the diversity in food production and natural resources, nutrition outcomes in the district remain poor (IFPRI, 2022), highlighting a need to explore the interlink between food environment, food insecurity and dietary diversity. A flow diagram depicting the sampling process and data collection is presented in Figure 1.

2.2 Sampling framework

The sampling framework is explained in Figure 1. In Srikakulam district of Andhra Pradesh, two sub-districts (a smaller administrative division within a district) were selected purposively, *Palasa* and *Srikakulam*, followed by selection of four blocks (two from each sub-district). In these blocks, the catchment panchayats (cluster of villages governed by rural local self-government system) catered by two specific Primary Health Care (PHC) centres (from each block) were listed. Out of these, one panchayat each was selected under these PHCs (i.e., a total of eight panchayats). This was followed by a random selection of two villages per panchayat resulting in the selection of 16 villages for data collection.

2.2.1 Sample size calculation

The sample size was calculated based on the prevalence of household food insecurity among similar communities in India. Based on a study from Andhra Pradesh (Satyanarayana and Babu, 2022), household food insecurity was found to be 64% among below poverty line households in *Guntur* district. Considering a prevalence of 50% to ensure a larger sample size, the study required 20 households each from 16 villages, to estimate the prevalence with 7% precision and 95% confidence level, assuming design effect of 1.5.

2.2.2 Selection of households

The inclusion criteria for households included the following: (a) household residing in the village for the past 1 year, (b) having an adult woman of reproductive age (18–49 years) (non-pregnant), and (c) consenting to participate in the survey. The survey was conducted on 328 eligible households selected by systematic random sampling. Within a village, a starting point was decided, and then every “*n*th” household was selected from that point onward based on the total number of households in the village.

2.3 Study procedures

A household survey was conducted to collect information on socio-economic and demographic profile, household's perception or lived experiences of their food environment (*n* = 328). The survey also assessed household food security status (*n* = 320) and dietary diversity of a randomly selected non-pregnant adult woman (18–49 years) present in the household (*n* = 320). The sample size varies across tools, as certain tools were administered only to specific household members; that were unavailable at the time of survey.

The study variables along with the tools used for their assessment are listed in Table 1.

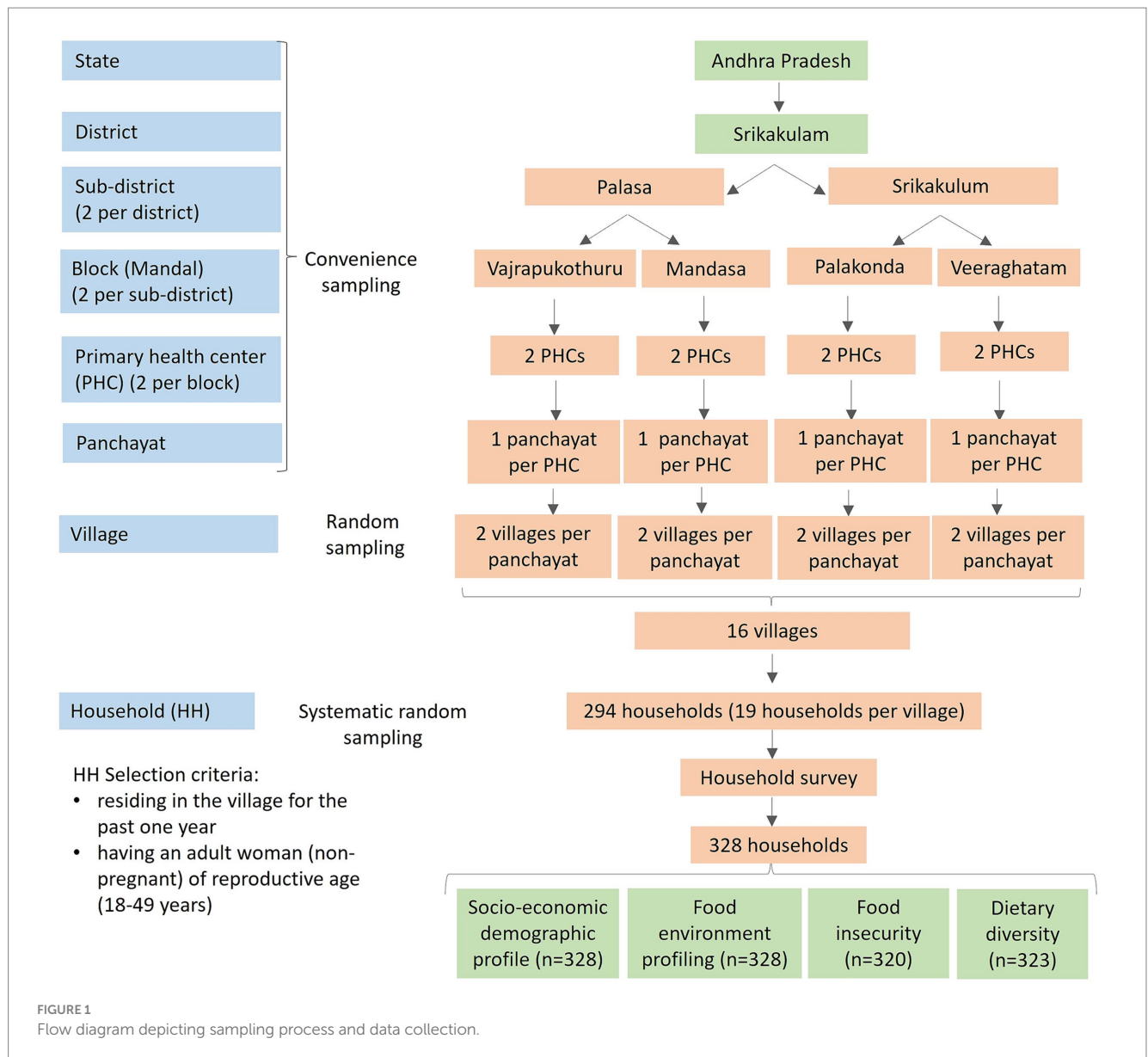
2.3.1 Study variables

2.3.1.1 Socio-economic and demographic profile

Information on household characteristics (such as family type, education, occupation, and access to government schemes) was elicited using a structured questionnaire administered on the head of household or any adult household member. Details about additional socio-economic characteristics, such as the type of house and its ownership, the presence of a separate kitchen and toilet, and the source of drinking water, were also collected.

2.3.1.2 Food environment of households

The food environment refers to the physical, economic, and socio-cultural surroundings where people access food, including the types of food available, their affordability, convenience, and how they are promoted (Downs et al., 2020). The perception or lived experiences of the respondents regarding their food environment were assessed using a tool called the “Food environment profiling questionnaire.” This tool is part of a food environment profiling toolkit developed by Downs et al. (2025). It aimed to explore the household's food access points, such as food items accessed from natural sources (such as farmland, kitchen garden, and domesticated animals) and built food environment (such as local market, and government food programs). Details about



perceptions on food availability, affordability, convenience, quality, safety, and promotion were also elicited.

2.3.1.3 Food security

Household food security was assessed using the eight-item Food Insecurity Experience Scale (FIES) tool (FAO, 2018a; Ballard et al., 2013). The tool captures self-reported behaviors and experiences related to food access in the household over the past 1 year. Any adult member of the household, preferably a female member (responsible for food preparation or distribution within the household), was asked to respond to eight questions, which were then analyzed to provide information on different levels of food insecurity (mild, moderate, and severe).

2.3.1.4 Dietary diversity

Dietary diversity refers to the intake of different food items or food groups over a specific time period (Kennedy et al., 2011). Minimum Dietary Diversity for Women (MDD-W) is a dietary

measure that assesses if minimum dietary diversity has been achieved during the day, which is reflected by the consumption of at least five different food groups out of the ten. A digital dietary diversity scoring tool was developed based on the MDD-W (FAO, 2021b) for assessing the diet quality of an adult woman (18–49 years) of reproductive age. The tool application had an in-built database of commonly consumed food items organized into various categories and sub-categories. The standardized amount of ingredients for each food item/dish was finalized using data from “Diet Cal” software (version 9) and a manual on standard recipes “Basic Food Preparation” (Raina et al., 2010). The amount of different ingredients for food items/dishes was based on one measuring cup (MC) or one serving size (SS). The ingredients were then classified into corresponding food groups for the calculation of the dietary diversity score. The interviews were conducted with women having a usual dietary intake on the previous day. Food items with amounts consumed (in household measures using a standardized set of measuring cups and spoons) on the previous day were entered meal-wise.

TABLE 1 Overview of study variables and tools.

| Study variable | Tool | Respondent | Data capture |
|--|--|--|--------------|
| Socio-economic and demographic profile | Household survey questionnaire | Head of household/any adult member of the household | Paper form |
| Food environment of households | Food environment profiling questionnaire | Any adult female member of the household (responsible for food preparation or distribution within the household) or any adult member/head of household | Paper form |
| Prevalence of food insecurity | Food insecurity experience scale (FIES) | Any adult female member of the household (responsible for food preparation or distribution within the household) or any adult member/head of household | Tablet |
| Dietary diversity score | Dietary diversity scoring tool | Adult woman of reproductive age (18 to 49 years) | Tablet |

2.3.2 Data collection

All the tools were prepared in English, then translated into Telugu, and pre-tested. Paper forms were used for household survey and food environment profiling questionnaire while data on food security and dietary diversity were collected using digital platform on tablets (Samsung Galaxy Tab A9). Trained field investigators conducted the surveys under the supervision of the core research team. In-depth hands-on training on obtaining consent from study participants, administering each tool, and online data syncing were provided. For data collected on tablets, the tool applications included built-in checks to ensure data quality. Collected data were synced at the end of each day to prevent any loss and were reviewed daily for discrepancies. Regular back-end data checks were performed to ensure data quality.

2.4 Data management

The data were exported in Microsoft Excel (MS Excel) sheets followed by manual cleaning and processing. Data collected using paper forms were entered in MS Excel sheet by two data entry operators. Validation checks were done to compare the two data sheets for any discrepancies. Additionally, data processing and cleaning were performed to remove incorrect or duplicated entries. All the data was stored in password-protected laptops to maintain data security.

2.5 Data analysis

For descriptive data analysis, continuous variables were presented as mean with standard deviation, while categorical variables were summarized using frequency with percentages. The results on households' perceived convenience in food availability, purchase, preparation by the households, food promotion and labelling was based on participants' perceptions and were collected through option-based questions. Simple descriptive data analysis was done by calculating the frequency and percentages of each option. Food Access Diversity Index (FADI) was calculated using data from the food environment profiling tool to assess agroforestry access diversity. To assess the diversity in dietary intake, Dietary Diversity Scores (DDS) were calculated using measures of food group consumption from MDD-W.

2.5.1 Food insecurity

Food insecurity was measured using FAO's eight-item food insecurity experience scale, in which participants responded to their difficulties in accessing food due to limited resources in past 12 months. Participants were categorized into four levels of food insecurity based on self-reported experiences in past 12 months. Individuals who reported being hungry but unable to eat, or who went without food for an entire day were categorized under severe food insecurity. Individuals who indicated skipping meals, reducing food intake, or exhausting available food supplies were categorized under moderate food insecurity. While individuals who expressed concern about insufficient food availability reported inability to consume a healthy and balanced diet or relied on a limited variety of foods were categorized under mild food insecurity. Individuals who did not report any of the aforementioned conditions were categorized as being food secure/no food insecurity. Later, food insecurity as ordinal variable with these four categories (none, mild, moderate, and severe) was used for regression analysis keeping none as reference category. Rasch model was used to check the validity of FIES scores, and their infit (<1.3) and outfit (<2.0) were within the limits for all items (FAO, 2018b).

2.5.2 Calculation of food access diversity index (FADI)

FADI provides detailed information about the different food items grown, accessed, and/or raised in households (Ghosh-Jerath et al., 2021). It has been adapted from the crop diversity index (Michler and Josephson, 2017). It was based on foods sourced from natural environment such as farmland, kitchen garden, forests and open fields, water sources, and domesticated animals. The index does not account for foods obtained from local market or government food programs. To calculate FADI, the total number of foods grown, gathered, or accessed, as well as animals raised in a household (n), was divided by the highest possible number of foods and animals that can be accessed or raised in the entire village (N). The final index is derived using the following equation:

$$FADI = \left(\frac{n}{N} \right)^2$$

A lower FADI value suggests reduced diversity in both food production and access, while a higher value indicates greater diversity.

2.5.3 Calculation of dietary diversity scores (DDS)

The average amount of food groups under each food item sub-category was calculated and recorded based on portion size consumed, i.e., one measuring cup (MC) or serving size (SS). According to the quantity of food item sub-category consumed (1 MC, 1/2 MC, 1/3 MC, 1/4 MC, 1 tablespoon, and 1 teaspoon), corresponding conversion factors were calculated (i.e., 1, 0.5, 0.3, 0.25, 0.06, 0.02). The amount of food groups in the consumed sub-category was multiplied by the respective conversion factor and the number of portions consumed (e.g., for 1/2 MC = 1 MC x 0.5 x no. of portions consumed). DDS is calculated based on the number of different food groups (out of 10) that a woman consumes over the past 24-hour period (FAO, 2021b). The maximum attainable score on the DDS tool was 10. The consumption of a particular food group was counted only if its intake was ≥ 15 g per day. All the amounts consumed in respective food groups across all the meals were added to arrive at the total food group intake throughout the day. By applying the threshold of 15 g for the food group consumed, a score of 1 or 0 was given. All the individual food group scores were summed up to compute the diet diversity score.

2.5.4 Statistical analysis

Simple and multiple variable mixed effect linear/binary logistic/ordinal logistic regressions (keeping blocks, panchayats, and villages as cluster levels) were used to check the associations between the outcomes (food insecurity and dietary diversity) and key variables. Univariable regression included fixed effect of variable of interest and random effect of blocks, panchayats, and villages and multi-variable regression included fixed effect of variable of interest along with key confounding variables (education and occupation of HH, availability of separate kitchen and source of drinking water) and random effects of blocks, panchayats, and villages. The odds ratio/beta estimates are presented along with their 95% confidence intervals and *p*-values. All results were tested at 5% level of significance. The analysis was done using R software version 4.4.1.

2.6 Ethical considerations

Ethical approval was taken from the Institutional Ethics Committee at The George Institute for Global Health, Delhi, India and Imperial College, London. Written consent at the panchayat level (rural local self-government system) from the panchayat head (i.e., *sarpanch*) were obtained before conducting surveys. All study participants were explained the study objectives and procedures. Additionally, they were assured that their information would be kept confidential, and any personal identifiable data would be anonymized during the analysis phase. Informed written consent was obtained from literate respondents and third-party witnessed verbal consent was sought from illiterate respondents, who agreed to participate. Participation in the study was entirely voluntary.

3 Results

3.1 Socio-economic and demographic profile of the community

The survey was conducted among 328 households from 16 villages in the Srikakulam district. The details of their socio-demographic characteristics are given in Table 2. The primary wage earner was typically the head of the household, with 43% having completed education upto high school. Their primary occupations were agriculture (45%) or daily wage labor (30%). Majority resided in *pucca* houses (88%) (characterized by walls and roofs made of durable materials such as bricks, stones, cement, or concrete), with 94% living in self-owned houses. Most of them (98%) held a Below Poverty Line (BPL) ration card for receiving Public Distribution System (PDS) services, a PFPP. Additionally, access to various government welfare schemes (excluding food programs) was widely reported, including *Navaratnalu*, (a set of welfare schemes in Andhra Pradesh) (75%), and the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) (36%).

3.2 Food environment of the households

3.2.1 Food accessed from different sources

Most households (93%) procured food from two to four sources, the common ones being local market (99%), government food programs (98%), farmland (69%), and domesticated animals (36%). The two main food source combinations were: farmland and local markets (47%), and local markets and government food programs (39%). Few (<10%) also procured food from kitchen garden, forest or open fields, friends, family and community, and water sources (such as pond, river, and sea). A mean FADI of 0.21 ± 0.29 (range: 0,1) was obtained, depicting poor diversity in food availability and access from natural sources.

Food groups procured by majority of households (>75%) from local market were other vegetables (94%), legumes, pulses, nuts, and seeds (88%), starchy staples (such as grains, cereals, and tubers) (78%), and other fruits (77%). Other important purchases included eggs (65%), sugars (60%), culinary ingredients (such as spices, tea) (59%), dark green leafy vegetables (54%), edible oils and fats (50%), unprocessed meat, fish and poultry, and milk and milk products (45%). Around a fourth of the households (<25%) also reported buying processed and ultra-processed foods such as sweetened beverages, meat, poultry and seafood, sweet, and salty foods. A smaller percentage of households (17%) purchased freshly prepared outside foods or street foods.

Under Government food programs, households reported accessing supplemental feeding programs—Public Distribution System (PDS; free/subsidized food grain distribution), Integrated Child Development Services (ICDS; take home ration (THR) and/or hot cooked meals (HCM) for children (6 months–6 years), pregnant and lactating mothers) and Pradhan Mantri Poshan Shakti Nirman (PMPOSHAN; mid-day meal for primary and upper-primary government school children). Nearly all (99%) accessed the PDS program. Most of these households (96%) received food commodities through PDS once a month. Of the

TABLE 2 Socio-economic and demographic profile of households ($n = 328$).

| Characteristics | Categories | Frequency (%) |
|--|--|---------------|
| Age of respondent (years) | 18–25 | 37 (11.3) |
| | 26–33 | 79 (24.1) |
| | 34–41 | 86 (26.2) |
| | 42–49 | 124 (37.8) |
| | ≥ 50 | 2 (0.6) |
| | Mean ± SD | 36.6 ± 8.29 |
| Gender of respondent | Male | 8 (2.4) |
| | Female | 320 (97.6) |
| Family type | Nuclear | 201 (61.3) |
| | Joint/extended/others | 127 (38.7) |
| Family members (mean ± SD) | Total no. of members | 4.15 ± 1.53 |
| | Total no. of adults (≥18 years) | 3.08 ± 1.15 |
| | Total no. of children and adolescents (6–18 years) | 0.79 ± 0.95 |
| | Total number of children < 5 years | 0.29 ± 0.64 |
| | Earning members | 1.45 ± 0.62 |
| Head of household as primary wage earner of the family | Yes | 321 (97.9) |
| | No | 7 (2.1) |
| Educational status of primary wage earner | Professional degree or above | 23 (7.0) |
| | Graduate | 26 (7.9) |
| | Intermediate or diploma | 39 (11.9) |
| | High school | 63 (19.2) |
| | Middle school | 34 (10.4) |
| | Primary school | 47 (14.3) |
| | Non-formal education | 15 (4.6) |
| | Illiterate | 81 (24.7) |
| Occupation of primary wage earner | Settled agriculture | 147 (44.8) |
| | Shifting cultivation | 1 (0.30) |
| | Craftsmen/artisans | 8 (2.4) |
| | Govt. or private/regular salary | 38 (11.6) |
| | Daily wager | 97 (29.6) |
| | Self-employed | 21 (6.4) |
| | Engaged in two occupations | 8 (2.4) |
| | Other | 8 (2.4) |
| Ration card possession ² | No | 8 (2.4) |
| | Yes | 320 (97.6) |
| Ration card type ($n = 320$) ² | <i>Antyodaya Anna Yojana (AAY)</i> | 5 (1.6) |
| | Below poverty line (BPL) | 314 (98.1) |
| | Others | 1 (0.3) |
| Type of house | Pucca | 290 (88.4) |
| | Semi-pucca | 25 (7.6) |
| | <i>Kuccha/Jhuggi</i> | 13 (4.0) |
| House ownership | Owned | 309 (94.2) |
| | Rented | 19 (5.8) |

(Continued)

TABLE 2 (Continued)

| Characteristics | Categories | Frequency (%) |
|---|--|---------------|
| Separate kitchen in the house | Yes | 249 (75.9) |
| | No | 79 (24.1) |
| Source of drinking water | Piped water | 229 (69.8) |
| | Protected well | 46 (14.0) |
| | Unprotected well | 9 (2.7) |
| | Tank | 6 (1.8) |
| | Tube well/hand-pump | 29 (8.8) |
| | Any other | 9 (2.7) |
| | Drinking water source location | Own household |
| | Neighbor's household | 18 (5.5) |
| | Own village | 111 (33.8) |
| | Another village | 2 (0.6) |
| | Any other | 4 (1.2) |
| Toilet in the household | Yes | 270 (82.3) |
| | No | 58 (17.7) |
| Toilet usage by household members ($n = 270$) | Yes | 268 (99.3) |
| | No | 2 (0.7) |
| Where do the family members go for defecation ($n = 60$) | Shared toilet (with other households) | 2 (3.3) |
| | Public/Community toilet | 1 (1.7) |
| | Open field/forest | 56 (93.3) |
| | Any other | 1 (1.7) |
| Access to Government schemes (other than Government food programs) ¹ | Mahatma Gandhi national rural employment guarantee Act (MGNREGA) | 118 (36.0) |
| | Pradhan Mantri Awas Yojana | 56 (17.1) |
| | <i>Navaratnalu</i> | 246 (75.0) |
| | <i>Upadi</i> NREGS (national rural employment guarantee scheme) | 1 (0.3) |
| Schemes under <i>Navaratnalu</i> ¹ ($n = 246$) | Y. S. Rajasekhara Reddy (YSR) <i>Raithu Bharosa</i> | 154 (62.6) |
| | Fee reimbursement | 20 (8.1) |
| | YSR <i>Arogyasri</i> | 109 (44.3) |
| | <i>Amma Vodi</i> | 110 (44.7) |
| | YSR Asara | 47 (19.1) |
| | Housing for all poor | 22 (8.9) |
| | Pensions-enhancement | 79 (32.1) |

¹ Multiple responses, sum of the percentages will not be equal to 100.

² Ration cards are essential for accessing the public distribution system (PDS), which is a public food procurement program (PFPP) aimed at ensuring food security for eligible households.

households surveyed that reported accessing Government food programs ($n = 321$), 13% availed services of the ICDS program and 31% availed services of the PMPOSHAN program. In these households, beneficiaries for ICDS comprised children aged 3–6 years (about two-thirds), children aged 6 months to 3 years (nearly half), and pregnant or lactating mothers (less than 10%). Nearly two-thirds of these households with children aged 6 months to 3 years, and all households with pregnant or lactating women reported receiving THR either fortnightly or once a month. In households with children aged 3 to 6 years, the majority

received HCM daily. Similarly, in most households who availed PM POSHAN scheme, regular (i.e., every working day) access to school meals was reported for eligible children.

In farmland ($n = 225$), the major crops grown were paddy (87%), followed by nuts and oil seeds (9%), fruit (7%), and pulses (2%). The minor crops grown were pulses (45%), nuts and oil seeds (16%), and millets (8%). Whereas in kitchen garden ($n = 29$) predominantly, households cultivated vegetables (72%) such as gourds, brinjal, drumstick, beans, followed by green leafy vegetables (21%) such as amaranth, sorrel (*gongura*), and a small

percentage cultivated fruits, paddy, pulses, yam, hibiscus, and chili (each around 3%). Commonly grown minor crops included vegetables (52%) and green leafy vegetables (34%). The most commonly owned or shared animals were cows (88%) followed by poultry (30%). The primary food items obtained from these animals were milk (89%) and eggs (30%). The commonly gathered food items from forests or open fields were other vegetable, fruits, and coconut. Some examples of food items accessed from kin (friends, family) and/or community (2%) were milk, vegetables, eggs, rice, wheat, and pulses.

3.2.2 Perceived affordability, quality, and safety of different food groups consumed

Households preferred to increase their purchase of legumes/pulses, nuts and seeds, other vegetables, and fruits if these items were more affordable or their income was higher (Figure 2). More than two-thirds of households expressed a desire for lower prices of legumes/pulses, nuts, and seeds (73%) and vegetables (73%). Up to two-thirds of households reported discounts or subsidies as reasons for purchasing legumes/pulses, nuts, and seeds (60%), and other vegetables (59%). The households expressed concerns regarding quality and safety of vegetables (57%) and other fruits (56%) procured from markets for household consumption.

3.2.3 Perceived convenience in food availability, purchase, and preparation by the households

Satisfaction with the availability and variety of food in their local community was expressed (either somewhat or strongly agreed) by nearly two-thirds of households (64%), while some expressed dissatisfaction (35%). Around half of them (53%) showed concern about the waning interest of younger generations towards consuming traditional foods. Almost all reported that female members of the household were primarily responsible for food preparation. Similarly, most decisions regarding the type of food to be prepared were also made by female members (91%). However, responsibility for purchasing food was relatively evenly distributed (in 54% of households being handled by female members and in 45% by male members).

3.2.4 Food promotion and labelling

Food promotions of any type were noticed by a majority (82%) in the last 30 days, with television being the most common source (93%), followed by shop wall writings/paintings (12%), posters/pamphlets (11%), and social media (6%). Seeing labels on packaged foods in places where they made their purchases was reported by 90% of respondents. The most observed details on labels included brand name (84%), cost (84%), and expiry or best-before dates (73%).



Whereas warning labels, nutrient or health claims, vegetarian/non-vegetarian color code, preparation/storage instructions, ingredient list, promotion character, serving size, and allergen information were reported to be observed by a few respondents (< 15%).

3.3 Food security status and dietary diversity of the community

Overall ($n = 320$), 40% of households were food secure, while 25% experienced mild, 23% moderate, and 12% experienced severe food insecurity. The mean DDS of women from these households was 4.39 ± 1.27 (range: 2–8), with 43% having a score of \geq five (Figure 3). However, more than three-fourths of the women (76%) scored between three and five.

Based on the cutoff of MDD-W (15 g per day), it was observed that for some of the food groups, only a few women (<25%) were consuming this minimal amount on the previous day. These were other fruits, nuts and seeds, other vitamin A-rich fruits and vegetables, dark green leafy vegetables, and eggs (Figure 4).

3.4 Interplay between socio-economic profile, food environment, food insecurity, and dietary diversity

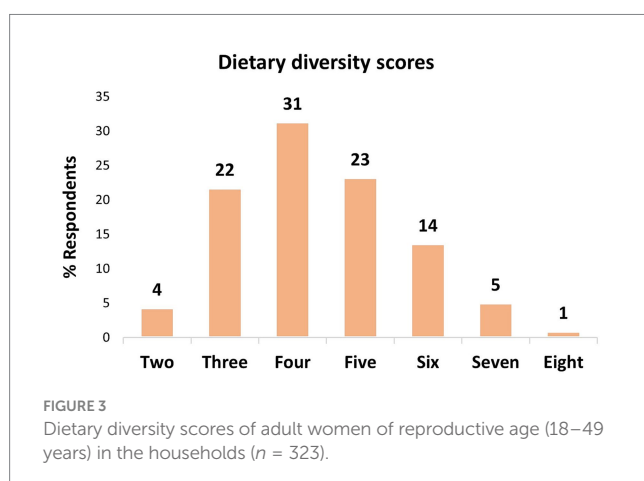
Univariable mixed-effects ordinal logistic regression revealed key factors associated with food insecurity (Table 3). Households with higher education levels, engaged in regular jobs or agriculture, and access to welfare schemes were significantly less likely to experience food insecurity. Specifically, households with wage earners who completed high school were 32% less likely (aOR = 0.68, 95% CI: 0.42, 1.11), while those with intermediate/diploma education or higher were 54% less likely (aOR = 0.46, 95% CI: 0.26, 0.80) to experience food insecurity compared to those with no formal education or illiterate. Type of employment was also found to be associated with a household's food insecurity. Wage earners in government or private services had a striking 77% lower odds of food insecurity (aOR = 0.23, 95% CI: 0.09, 0.57), and those in agriculture were 59% less likely to experience food insecurity (aOR = 0.41, 95% CI: 0.22, 0.78). In

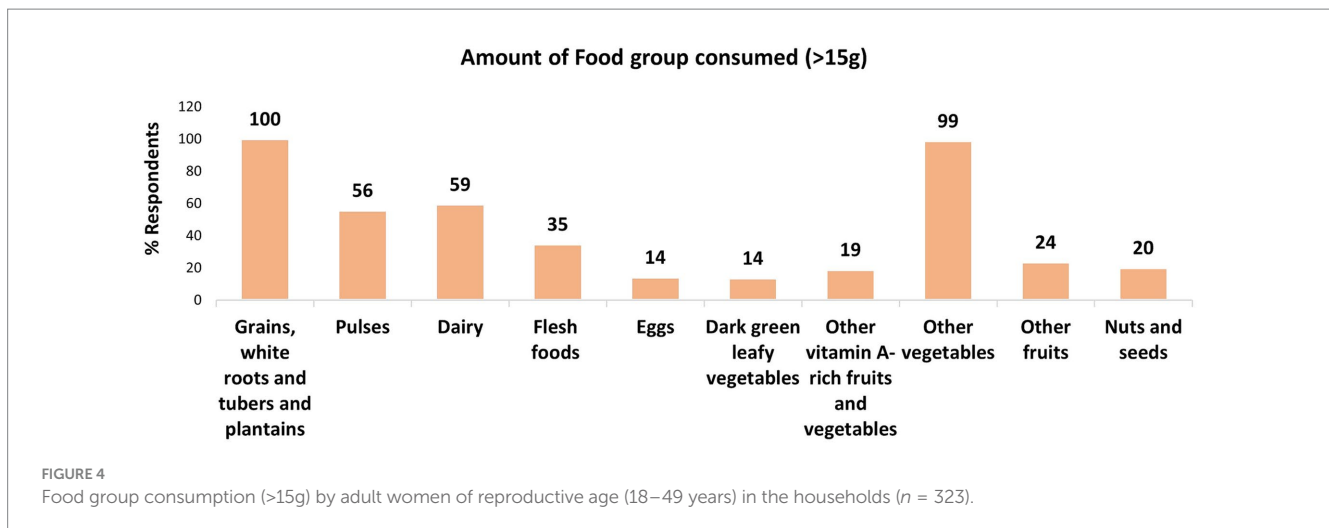
contrast, daily wage earners faced a 6% higher likelihood of food insecurity (aOR = 1.06, 95% CI: 0.52, 2.16) compared to those working as craftsmen, artisans, or were self-employed. Households getting support from the Government scheme YSR *Raithu Bharosa*, which provides financial assistance to farmers, were 52% less likely to experience food insecurity than those not availing it (aOR = 0.48, 95% CI: 0.29, 0.79). Additionally, women with a DDS of ≥ 5 were 37% less likely to experience higher food insecurity (aOR = 0.61, 95% CI: 0.41, 0.96) (not shown in Table).

Further analysis, using univariable mixed-effects binary logistic and linear regression, highlighted key determinants of dietary diversity among women (Table 4). Women from mild, moderate, and severe food-insecure households had 0.06 units (CI: -0.41, 0.29), 0.41 units (CI: -0.76, -0.06), and 0.49 units (CI: -0.94, -0.04) lower DDS, respectively, compared to those from food-secure households ($p = 0.040$) (Table 4). Women from households without a separate kitchen were 57% less likely to have DDS of ≥ 5 (aOR = 0.43, 95% CI: 0.23, 0.79) (Table 1, Supplementary material S1) and had a DDS score of 0.41 units lower ($p < 0.05$, 95% CI: -0.73, -0.09) than those with a separate kitchen space (Table 4). In contrast, access to homegrown food made a substantial difference, women accessing food from a kitchen garden were 2.11 times more likely to have higher (≥ 5) DDS (aOR = 3.11, 95% CI: 1.31, 7.39) (Table 1, Supplementary material S1) and had 0.58 units higher DDS ($p < 0.05$, 95% CI: 0.11, 1.0) than those who did not (Table 4). Government housing and healthcare programs were also associated with dietary diversity. Women from households not benefiting from the *Pradhan Mantri Awas Yojana* (a government initiative to provide affordable housing) were 52% less likely to have a DDS of ≥ 5 (aOR = 0.48, 95% CI: 0.24, 0.96) (Table 1, Supplementary material S1). Meanwhile, those from households who were using YSR *Arogyasri* scheme (a government health care scheme for economically disadvantaged families) were 2.17 times more likely to have higher (≥ 5) DDS (aOR = 3.17, 95% CI: 1.56, 6.42) (Table 1, Supplementary material S1) and had 0.50 unit higher DDS ($p = 0.008$, 95% CI: 0.13, 0.87) than those who were not enrolled in this scheme (Table 4).

Multiple variable mixed effect regression showed households where the primary earners worked as daily wagers were 40% more likely to be food insecure than those engaged in other occupations such as craftsmen/artisans, self-employed, and others (aOR = 1.40, 95% CI: 0.53, 3.73) (Table 3). In contrast, households where the primary earners held regular salaried government or private jobs were 75% less likely to experience food insecurity (aOR = 0.25, 95% CI: 0.07, 0.95), and those involved in agriculture were 57% less likely (aOR = 0.43, 95% CI: 0.16, 1.17) compared to other occupations. Households that accessed food from farmland were found to be 47% less likely to be food insecure compared to those that did not (aOR = 0.53, 95% CI: 0.33, 0.85) (Table 3). Women's dietary diversity was also found to be significantly associated with food insecurity. Women with a DDS of ≥ 5 were 55% less likely to be food insecure ($p < 0.01$, 95% CI: 0.26, 0.78) (not shown in Table).

In terms of dietary diversity, women from mild, moderate, and severe food-insecure households had 0.04 units (CI: -0.46 to 0.37), 0.38 units (CI: -0.80 to 0.04), and 0.72 units (CI: -1.3 to -0.14) lower DDS, respectively, compared to those from food-secure households ($p = 0.042$) (Table 4). Also, women from moderately and severely food-insecure households were 58% (aOR:0.42, CI: 0.17, 1.02) and 59% (aOR: 0.41, CI:0.12, 1.32) less likely to have a DDS of ≥ 5 ,





respectively, compared to those from food-secure households (Table 1, Supplementary material S1). Furthermore, women from households without a separate kitchen had 0.52 units lower DDS than those from households with a separate kitchen ($p < 0.05$, 95% CI: $-0.98, -0.07$). When DDS of the women in the households were considered in general, access to food from a kitchen garden was also associated with an increase of 0.68 units in DDS ($p < 0.05$, 95% CI: 0.20, 1.2), while access to food from forests or open fields was linked to a 1.2 unit increase in DDS ($p < 0.05$, 95% CI: 0.20, 2.1). On the other hand, when we considered households with an acceptable DDS (≥ 5) vs. poor DDS (< 5), women from households that accessed food from a kitchen garden were 2.32 times more likely to have an acceptable DDS (aOR = 3.32, $p < 0.05$, 95% CI: 1.36, 8.09) (Table 2, Supplementary material S1).

4 Discussion

In the present study, we have explored the food environment and assessed the household-level food security, and dietary diversity in women of reproductive age in a rural community in Andhra Pradesh. Most households reported access to two to four major food sources, primarily through local markets and government food programs (PDS, ICDS and PMPOSHAN), alongside natural sources such as farmland and domesticated animals. Almost 40% of households were food secure. Around 43% of the women had optimal dietary diversity with a score (DDS) of ≥ 5 . Stable sources of income, possession of agricultural land and engagement in farming, access to a kitchen garden, access to government welfare schemes, and better dietary diversity had a lesser likelihood of food insecurity at the household level. Determinants of dietary diversity included better household food security, availability of a separate kitchen in the house (a proxy for economic status), a kitchen garden, and access to government welfare schemes, with better access to these leading to higher DDS.

The community studied reported access to local markets, majorly for vegetables, legumes, pulses, nuts, and seeds, followed by starchy staples and fruits while fewer households relied on markets for protein-rich foods like eggs, meat, and milk and milk products. Another study among rural communities in the nearby state of Telangana reported that food items such as tea, coffee, sweets, snacks (e.g., biscuits, cakes,

and fried savoury snacks), alcoholic and non-alcoholic beverages, followed by carbohydrate and fat-rich food groups were easily accessible in markets (Kumar et al., 2023). This community also reported discretionary foods, followed by carbohydrate-rich foods, being more affordable and convenient. In the present study, the community reported issues around the affordability of commodities such as legumes/pulses, nuts and seeds, vegetables, and fruits, and expressed a desire to purchase more of these items had they been affordable or if their income was higher. Studies conducted in rural food environments in India have often highlighted a carbohydrate-heavy diet with increasing access to street foods, sweets, and deep-fried savory snacks (Gupta et al., 2016). Our study has also reported variable intake of processed freshly prepared outside foods or street foods, and ultra-processed foods such as sweetened beverages, sweet, and salty packaged foods. A possible reason for increased access to nutrient-poor and high-energy, fat, salt, and sugar foods from the market quoted in other studies includes aggressive marketing strategy and infiltration of rural economies with affordable, small packaged, high-energy and sugary foods, resulting in their increased consumption.

In the present study, forest and water bodies were accessed minimally by our community. Studies have cited reasons for this decline in foraging, which include high opportunity cost in terms of the amount of time and energy required to forage, and erosion in the traditional indigenous knowledge on foods that can be accessed from these natural food access points (Wolfe, 2013; Ghosh-Jerath et al., 2016a; Ghosh-Jerath et al., 2016b). The other reason could be decreasing natural resources resulting from climate change and deforestation, thereby leading to reduced use of forest resources and water bodies for food (Mishra, 2017).

In another study conducted in rural areas of Andhra Pradesh, a similar level of food security (45%) was observed as reported in the present study (Satyanarayana and Babu, 2022). Dietary diversity in the present study was associated with food security. Also, access to a natural food environment for household consumption, such as owning a kitchen garden and engagement in agricultural practices, was associated both with food security and dietary diversity. In rural Bangladesh, a home garden model has reported improved intake of fresh fruits and vegetables, reduced expenses on vegetables, along with a potential income generation model by the sale of the produce (Ferdous et al., 2016). Similarly, through community-led kitchen garden models created by UNICEF in Chhattisgarh, India have been

TABLE 3 Association of household food insecurity with socio-demographic characteristics, food sources accessed, and dietary diversity (n = 320).

| Characteristic | Household food insecurity n (%) | | | | Mixed effect ordinal logistic regression | | | |
|---|---------------------------------|------------|------------------------|------------|--|------------------|--|------------------|
| | | | | | (reference: none) | | | |
| | Univariable analysis | | Multivariable analysis | | OR ¹ (95% CI ²) | p-value | OR ¹ (95% CI ²) | p-value |
| | None | Mild | Moderate | Severe | | | | |
| Education of primary wage earner (n = 320) | | | | | | 0.025 | | 0.4 |
| Illiterate or non-formal education (n = 93) | 26 (27.96) | 24 (25.81) | 33 (35.48) | 10 (10.75) | – | | – | |
| Primary to high school (n = 140) | 58 (41.43) | 35 (25.00) | 30 (21.43) | 17 (12.14) | 0.68 (0.42, 1.11) | | 0.67 (0.36, 1.25) | |
| Intermediate/diploma and above (n = 87) | 45 (51.72) | 20 (22.99) | 12 (13.79) | 10 (11.49) | 0.46 (0.26, 0.80) | | 0.87 (0.40, 1.88) | |
| Occupation of primary wage earner (n = 320) | | | | | | <0.001 | | <0.001 |
| Other (Craftsmen/artisans, self-employed and others) (n = 38) | 8 (21.05) | 11 (28.95) | 13 (34.21) | 6 (15.79) | – | | – | |
| Service (Govt. or Private)/regular salary (n = 37) | 23 (62.16) | 9 (24.32) | 4 (10.81) | 1 (2.70) | 0.23 (0.09, 0.57) | | 0.25 (0.07, 0.95) | |
| Daily wager (n = 95) | 27 (28.42) | 25 (26.32) | 24 (25.26) | 19 (20.00) | 1.06 (0.52, 2.16) | | 1.40 (0.53, 3.73) | |
| Agriculture (n = 150) | 71 (47.33) | 34 (22.67) | 34 (22.67) | 11 (7.33) | 0.41 (0.22, 0.78) | | 0.43 (0.16, 1.17) | |
| Separate kitchen in the house (n = 320) | | | | | | 0.96 | | 0.4 |
| Yes (n = 243) | 101 (41.56) | 56 (23.05) | 55 (22.63) | 31 (12.76) | – | | – | |
| No (n = 77) | 28 (36.36) | 23 (29.87) | 20 (25.97) | 6 (7.79) | 1.01 (0.62, 1.64) | | 0.73 (0.37, 1.46) | |
| Main source of drinking water for the household (n = 320) | | | | | | 0.61 | | 0.4 |
| Other (n = 98) | 46 (46.94) | 17 (17.35) | 23 (23.47) | 12 (12.24) | – | | – | |
| Piped (n = 222) | 83 (37.39) | 62 (27.93) | 52 (23.42) | 25 (11.26) | 1.13 (0.71, 1.79) | | 1.30 (0.73, 2.33) | |
| Accessing food from Anganwadi centre (ICDS) (n = 313) | | | | | | 0.31 | | >0.9 |
| No (n = 270) | 101 (37.41) | 72 (26.67) | 65 (24.07) | 32 (11.85) | – | | – | |
| Yes (n = 43) | 21 (48.84) | 7 (16.28) | 10 (23.26) | 5 (11.63) | 0.72 (0.39, 1.34) | | 1.02 (0.39, 2.64) | |
| Accessing food from PM POSHAN mid-day meal program (n = 313) | | | | | | 0.48 | | 0.8 |
| No (n = 215) | 84 (39.07) | 51 (23.72) | 52 (24.19) | 28 (13.02) | – | | – | |

(Continued)

TABLE 3 (Continued)

| Characteristic | Household food insecurity <i>n</i> (%) | | | | Mixed effect ordinal logistic regression | | | |
|---|--|------------|------------|------------|--|--|------------------------|------|
| | | | | | (reference: none) | | | |
| | None | Mild | Moderate | Severe | Univariable analysis | | Multivariable analysis | |
| OR ¹ (95% CI ²) | | | | | <i>p</i> -value | OR ¹ (95% CI ²) | <i>p</i> -value | |
| Yes (<i>n</i> = 98) | 38 (38.78) | 28 (28.57) | 23 (23.47) | 9 (9.18) | 0.85 (0.55, 1.32) | | 1.09 (0.52, 2.29) | |
| Accessing Government welfare scheme—MGNREGA (<i>n</i> = 320) | | | | | | 0.34 | | >0.9 |
| Yes (<i>n</i> = 116) | 45 (38.79) | 31 (26.72) | 30 (25.86) | 10 (8.62) | – | | – | |
| No (<i>n</i> = 204) | 84 (41.18) | 48 (23.53) | 45 (22.06) | 27 (13.24) | 1.25 (0.79, 2.00) | | 0.98 (0.52, 1.84) | |
| Accessing government welfare scheme—Pradhan Mantri Awas Yojana (<i>n</i> = 320) | | | | | | 0.61 | | >0.9 |
| Yes (<i>n</i> = 56) | 18 (32.14) | 19 (33.93) | 13 (23.21) | 6 (10.71) | – | | – | |
| No (<i>n</i> = 264) | 111 (42.05) | 60 (22.73) | 62 (23.48) | 31 (11.74) | 0.87 (0.51, 1.49) | | 1.05 (0.45, 2.42) | |
| Accessing government welfare schemes under Navaratnalu (<i>n</i> = 320) | | | | | | 0.32 | — | — |
| Yes (<i>n</i> = 240) | 99 (41.25) | 62 (25.83) | 53 (22.08) | 26 (10.83) | – | | | |
| No (<i>n</i> = 80) | 30 (37.50) | 17 (21.25) | 22 (27.50) | 11 (13.75) | 1.28 (0.79, 2.05) | | | |
| Accessing Navaratnalu scheme—YSR Raithu Bharosa (<i>n</i> = 240) | | | | | | 0.004 | – | – |
| No (<i>n</i> = 89) | 27 (30.34) | 25 (28.09) | 21 (23.60) | 16 (17.98) | – | | | |
| Yes (<i>n</i> = 151) | 72 (47.68) | 37 (24.50) | 32 (21.19) | 10 (6.62) | 0.48 (0.29, 0.79) | | | |
| Accessing Navaratnalu scheme—fee reimbursement, youth employment and job creation (<i>n</i> = 240) | | | | | | 0.34 | – | – |
| No (<i>n</i> = 222) | 94 (42.34) | 56 (25.23) | 47 (21.17) | 25 (11.26) | – | | | |
| Yes (<i>n</i> = 18) | 5 (27.78) | 6 (33.33) | 6 (33.33) | 1 (5.56) | 1.52 (0.65, 3.54) | | | |
| Accessing Navaratnalu scheme—YSR Arogyasri (<i>n</i> = 240) | | | | | | 0.021 | | 0.2 |
| No (<i>n</i> = 133) | 61 (45.86) | 30 (22.56) | 31 (23.31) | 11 (8.27) | – | | – | |
| Yes (<i>n</i> = 107) | 38 (35.51) | 32 (29.91) | 22 (20.56) | 15 (14.02) | 1.99 (1.11, 3.57) | | 1.61 (0.83, 3.13) | |
| Accessing Navaratnalu scheme—Amma Vodi (<i>n</i> = 240) | | | | | | 0.95 | | 0.8 |

(Continued)

TABLE 3 (Continued)

| Characteristic | Household food insecurity <i>n</i> (%) | | | | Mixed effect ordinal logistic regression | | | |
|---|--|-------------|------------------------|-------------|--|-----------------|--|------------------|
| | | | | | (reference: none) | | | |
| | Univariable analysis | | Multivariable analysis | | OR ¹ (95% CI ²) | | <i>p</i> -value | |
| | None | Mild | Moderate | Severe | OR ¹ (95% CI ²) | <i>p</i> -value | OR ¹ (95% CI ²) | <i>p</i> -value |
| No (<i>n</i> = 132) | 57 (43.18) | 32 (24.24) | 26 (19.70) | 17 (12.88) | – | | – | |
| Yes (<i>n</i> = 108) | 42 (38.89) | 30 (27.78) | 27 (25.00) | 9 (8.33) | 0.99 (0.61, 1.59) | | 1.12 (0.53, 2.36) | |
| Accessing Navaratmalu scheme—YSR Asara, YSR Cheyuta (<i>n</i> = 240) | | | | | | 0.19 | | 0.4 |
| No (<i>n</i> = 194) | 80 (41.24) | 50 (25.77) | 45 (23.20) | 19 (9.79) | – | | – | |
| Yes (<i>n</i> = 46) | 19 (41.30) | 12 (26.09) | 8 (17.39) | 7 (15.22) | 1.57 (0.80, 3.08) | | 1.40 (0.68, 2.88) | |
| Accessing Navaratmalu scheme—housing for all poor (<i>n</i> = 240) | | | | | | 0.41 | – | – |
| No (<i>n</i> = 218) | 92 (42.20) | 56 (25.69) | 48 (22.02) | 22 (10.09) | – | | | |
| Yes (<i>n</i> = 22) | 7 (31.82) | 6 (27.27) | 5 (22.73) | 4 (18.18) | 1.41 (0.62, 3.19) | | | |
| Accessing Navaratmalu scheme—pensions—enhancement (<i>n</i> = 240) | | | | | | 0.74 | | 0.13 |
| No (<i>n</i> = 164) | 64 (39.02) | 46 (28.05) | 39 (23.78) | 15 (9.15) | – | | – | |
| Yes (<i>n</i> = 76) | 35 (46.05) | 16 (21.05) | 14 (18.42) | 11 (14.47) | 0.91 (0.54, 1.55) | | 0.62 (0.33, 1.15) | |
| Total number of food sources accessed (<i>n</i> = 320) Mean (SD³) | 3.28 (0.96) | 3.06 (0.91) | 3.08 (0.83) | 3.08 (1.04) | 0.85 (0.68, 1.06) | 0.14 | 1.93 (0.68, 5.49) | 0.2 |
| Accessing food from kitchen garden (<i>n</i> = 320) | | | | | | 0.72 | | 0.2 |
| No (<i>n</i> = 292) | 116 (39.73) | 73 (25.00) | 69 (23.63) | 34 (11.64) | – | | – | |
| Yes (<i>n</i> = 28) | 13 (46.43) | 6 (21.43) | 6 (21.43) | 3 (10.71) | 0.87 (0.42, 1.82) | | 0.42 (0.10, 1.82) | |
| Food access diversity index (<i>n</i> = 320) mean (SD³) | 0.24 (0.30) | 0.20 (0.30) | 0.20 (0.30) | 0.18 (0.28) | 0.60 (0.29, 1.22) | 0.16 | – | – |
| Dietary diversity score (<i>n</i> = 316) | 128 (40.5) | 77 (24.4) | 75 (23.7) | 36 (11.4) | 0.79 (0.67, 0.93) | 0.005 | 0.70 (0.56, 0.87) | <0.001 |
| Mean (SD ³) | 4.58 (1.41) | 4.56 (1.30) | 4.09 (1.00) | 4.00 (1.10) | | | | |
| Accessing food from Farmland | | | | | | | | 0.008 |
| Yes (<i>n</i> = 220) | 100 (45.45) | 51 (23.18) | 47 (21.36) | 22 (10.00) | – | – | 0.53 (0.33, 0.85) | |
| No (<i>n</i> = 100) | 29 (29.00) | 28 (28.00) | 28 (28.00) | 15 (15.00) | – | – | – | |
| Accessing food from kitchen garden | | | | | | | | >0.9 |

(Continued)

TABLE 3 (Continued)

| Characteristic | Household food insecurity <i>n</i> (%) | | | | Mixed effect ordinal logistic regression | | | |
|---|--|------------|------------|------------|--|--|------------------------|-----|
| | | | | | (reference: none) | | | |
| | None | Mild | Moderate | Severe | Univariable analysis | | Multivariable analysis | |
| OR ¹ (95% CI ²) | | | | | <i>p</i> -value | OR ¹ (95% CI ²) | <i>p</i> -value | |
| Yes (<i>n</i> = 28) | 13 (46.43) | 6 (21.43) | 6 (21.43) | 3 (10.71) | – | – | 1.04 (0.48, 2.29) | |
| No (<i>n</i> = 292) | 116 (39.73) | 73 (25.00) | 69 (23.63) | 34 (11.64) | – | – | – | |
| Accessing food from domesticated animals | | | | | | | | 0.9 |
| Yes (<i>n</i> = 117) | 53 (45.30) | 25 (21.37) | 28 (23.93) | 11 (9.40) | – | – | 0.97 (0.61, 1.52) | |
| No (<i>n</i> = 203) | 76 (37.44) | 54 (26.60) | 47 (23.15) | 26 (12.81) | – | – | – | |

¹OR, odds ratio.²CI, confidence interval.³SD, standard deviation. *p*<0.05 values are highlighted in bold.

able to promote nutrition levels, livelihood, and improved indicators of food security, and a reduction in the incidence of diseases associated with malnutrition (Suri, 2020).

The present study documents the interplay of food environment, food security, and dietary diversity in a rural community of Andhra Pradesh. It highlights the need for an integrated approach that can address food insecurity in the rural Indian community while giving due attention to the food environment, especially the natural food environment that continues to contribute to dietary intake, diet diversity, and food security. Nutritional enhancement of the population through sustainable food systems strengthening and food-based interventions to address malnutrition has gained renewed attention at the highest level of policymaking. The *Poshan* (nutrition) 2.0 (MSME, 2021), development of Nutrition Atlas by the Indian Council of Medical Research (ICMR)—National Institute of Nutrition (NIN) (ICMR-NIN, 2024) and *Poshan Atlas* by the Ministry of Women and Child Development (MoWCD, 2024), nutri-garden initiative for schools and AWCs in various states of India, and the diversification of PDS as part of the revamping efforts (National Food Security Act, 2013) indicate the potential of strengthening food systems through its PFPPs a significant step towards addressing double burden of malnutrition in India. Interventions such as home-grown school feeding programs globally (Silva et al., 2023), home garden, and backyard poultry intervention, along with relevant social and behavior change communication strategies, have led to a significant increase in consumption of green leafy vegetables and eggs among women and children leading to dietary diversification (Murty et al., 2016; Ch et al., 2024; Pradhan et al., 2018). Also, a study conducted in Odisha and Tamil Nadu using a combination of interviews and focus groups revealed that incorporating nutrition-sensitive methods into agriculture helped diversify home gardens and enhance participants' nutrition awareness (Jaleel et al., 2025). Connecting nutri-gardens to institutions that are engaging in supplementary feeding of vulnerable age groups and populations, such as schools, AWCs can be a sustainable strategy to provide

fresh, local food commodities while also contributing to reducing food miles (FAO and WFP, 2018). Improved access to agricultural advisory services and skill-based and entrepreneurship training can create additional employment and strengthen household incomes (IFAD, ILO, and UNDP, 2016). Additionally, strengthened implementation and continuous monitoring of Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) are essential, particularly among vulnerable communities, since access to such wage-employment programmes directly influences their nutritional outcomes (Kumara and Musthafab, 2024).

5 Conclusion

The rural community studied needs targeted interventions to enhance food security and dietary quality. Nearly half of the study households experienced mild to moderate food insecurity, indicating a pressing concern. More than half of the women interviewed had DDS < 5, suggesting potential micronutrient deficiencies. The community primarily accessed food through local markets, PFPPs, and farmland. Promotion of local farming with the utilization of diverse regional crops and linking them with PFPPs is likely to strengthen local food systems and result in improved dietary diversity and food security. The findings of the present study establish an important premise for developing a nutrition-sensitive intervention that can create an enabling food environment by reviving traditional agricultural and food production practices that diversify the food plates of rural communities, leading to dietary diversification and food security.

6 Strengths and limitations

The present study is one of the few in the Indian rural context to simultaneously assess food environment characteristics, household food security, and women's dietary diversity, providing a systems-level understanding rather than examining these

TABLE 4 Association of dietary diversity of women (18–49 years) with socio-demographic characteristics and food sources accessed (n = 323).

| Characteristic | Dietary diversity score (DDS) Mean ± SD ¹ | Mixed-effect linear regression | | | | | |
|---|---|--------------------------------|---------------------|--------------|------------------------|---------------------|--------------|
| | | Univariable analysis | | | Multivariable analysis | | |
| | | Beta | 95% CI ² | p-value | Beta | 95% CI ² | p-value |
| Education of primary wage earner (n = 323) | | | | 0.5 | | | 0.3 |
| Illiterate or non-formal education | 4.26 ± 1.26 | – | – | | – | – | |
| Primary to high school | 4.38 ± 1.18 | 0.1 | –0.24, 0.43 | | 0.26 | –0.14, 0.66 | |
| Intermediate/diploma and above | 4.53 ± 1.41 | 0.22 | –0.15, 0.59 | | –0.01 | –0.48, 0.47 | |
| Occupation of primary wage earner (n = 323) | | | | 0.069 | | | 0.4 |
| Other (craftsmen/artisans, self-employed and others) | 4.37 ± 1.28 | – | – | | – | – | |
| Service (Govt. or private)/regular salary | 4.81 ± 1.31 | 0.42 | –0.15, 1.0 | | 0.3 | –0.54, 1.1 | |
| Daily wager | 4.47 ± 1.29 | 0.14 | –0.34, 0.63 | | 0.02 | –0.68, 0.71 | |
| Agriculture | 4.23 ± 1.23 | –0.14 | –0.58, 0.30 | | –0.24 | –0.91, 0.43 | |
| Separate kitchen in the house (n = 323) | | | | 0.011 | | | 0.024 |
| Yes | 4.48 ± 1.31 | – | – | | – | – | |
| No | 4.09 ± 1.10 | –0.41 | –0.73, –0.09 | | –0.52 | –0.98, –0.07 | |
| Main source of drinking water for the household (n = 323) | | | | 0.5 | | | 0.7 |
| Other | 4.46 ± 1.33 | – | – | | – | – | |
| Piped | 4.35 ± 1.25 | –0.11 | –0.42, 0.20 | | –0.07 | –0.44, 0.31 | |
| Food access diversity index (n = 323) | 4.39 ± 1.27 | 0.16 | –0.32, 0.63 | 0.5 | – | – | – |
| Accessing government welfare scheme—MGNREGA (n = 323) | | | | 0.041 | | | >0.9 |
| Yes | 4.22 ± 1.24 | – | – | | – | – | |
| No | 4.48 ± 1.28 | 0.31 | 0.01, 0.62 | | 0.01 | –0.41, 0.43 | |
| Accessing government welfare scheme—Pradhan Mantri Awas Yojana (n = 323) | | | | 0.075 | | | 0.4 |
| Yes | 4.60 ± 1.18 | – | – | | – | – | |
| No | 4.34 ± 1.29 | –0.34 | –0.72, 0.03 | | –0.24 | –0.79, 0.31 | |
| Accessing government welfare schemes under Navaratnalu (n = 323) | | | | 0.2 | | | – |
| Yes | 4.45 ± 1.30 | – | – | | – | – | |
| No | 4.19 ± 1.17 | –0.2 | –0.51, 0.11 | | | | |
| Accessing Navaratnalu scheme—YSR Raithu Bharosa (n = 243) | | | | 0.2 | | | 0.3 |

(Continued)

TABLE 4 (Continued)

| Characteristic | Dietary diversity score (DDS) Mean ± SD ¹ | Mixed-effect linear regression | | | | | |
|--|---|--------------------------------|---------------------|--------------|------------------------|---------------------|--------------|
| | | Univariable analysis | | | Multivariable analysis | | |
| | | Beta | 95% CI ² | p-value | Beta | 95% CI ² | p-value |
| No | 4.24 ± 1.26 | - | - | | - | - | |
| Yes | 4.58 ± 1.31 | 0.24 | -0.09, 0.57 | | 0.22 | -0.17, 0.62 | |
| Accessing Navaratnalu scheme—Fee reimbursement, youth employment and job creation (n = 243) | | | | 0.9 | - | - | - |
| No | 4.46 ± 1.34 | - | - | | | | |
| Yes | 4.40 ± 0.68 | 0.05 | -0.53, 0.63 | | | | |
| Accessing Navaratnalu scheme—YSR Arogyasri (n = 243) | | | | 0.008 | | | 0.5 |
| No | 4.32 ± 1.33 | — | — | | — | — | |
| Yes | 4.62 ± 1.25 | 0.5 | 0.13, 0.87 | | 0.16 | -0.29, 0.61 | |
| Accessing Navaratnalu scheme—Amma Vodi (n = 243) | | | | 0.13 | | | 0.6 |
| No | 4.57 ± 1.36 | - | - | | - | - | |
| Yes | 4.31 ± 1.21 | -0.24 | -0.56, 0.07 | | -0.11 | -0.56, 0.35 | |
| Accessing Navaratnalu scheme—YSR Asara, YSR Cheyuta (n = 243) | | | | 0.11 | | | 0.3 |
| No | 4.40 ± 1.31 | - | - | | - | - | |
| Yes | 4.68 ± 1.22 | 0.34 | -0.08, 0.76 | | 0.26 | -0.20, 0.72 | |
| Accessing Navaratnalu scheme—housing for all poor (n = 243) | | | | 0.9 | - | - | - |
| No | 4.46 ± 1.30 | - | - | | | | |
| Yes | 4.41 ± 1.30 | 0.05 | -0.51, 0.60 | | | | |
| Accessing Navaratnalu scheme—pensions—enhancement (n = 243) | | | | 0.4 | | | 0.4 |
| No | 4.52 ± 1.36 | - | - | | - | - | |
| Yes | 4.32 ± 1.16 | -0.15 | -0.49, 0.19 | | -0.17 | -0.55, 0.20 | |
| Accessing food from kitchen garden (n = 323) | | | | 0.016 | | | 0.05 |
| No | 4.34 ± 1.27 | - | - | | - | - | |
| Yes | 4.86 ± 1.24 | 0.58 | 0.11, 1.0 | | 0.84 | 0.00, 1.7 | |
| Total number of crops grown in kitchen garden (n = 29) | 4.86 ± 1.24 | 0.01 | -0.19, 0.22 | >0.9 | - | - | - |
| Total number of food sources accessed (n = 323) | 4.39 ± 1.27 | -0.01 | -0.16, 0.13 | 0.9 | 0.23 | -0.39, 0.85 | 0.5 |
| Food insecurity (n = 316) | | | | 0.040 | | | 0.042 |
| None | 4.58 ± 1.41 | - | - | | - | - | |
| Mild | 4.56 ± 1.30 | -0.06 | -0.41, 0.29 | | -0.04 | -0.46, 0.37 | |
| Moderate | 4.09 ± 1.00 | -0.41 | -0.76, -0.06 | | -0.38 | -0.80, 0.04 | |

(Continued)

TABLE 4 (Continued)

| Characteristic | Dietary diversity score (DDS) Mean ± SD ¹ | Mixed-effect linear regression | | | | | |
|--|---|--------------------------------|---------------------|-----------------|------------------------|---------------------|-----------------|
| | | Univariable analysis | | | Multivariable analysis | | |
| | | Beta | 95% CI ² | <i>p</i> -value | Beta | 95% CI ² | <i>p</i> -value |
| Severe | 4.00 ± 1.10 | -0.49 | -0.94, -0.04 | | -0.72 | -1.3, -0.14 | |
| Accessing food from Farmland (<i>n</i> = 323) | | | | 0.76 | | | 0.6 |
| No | 4.34 ± 1.29 | - | - | | - | - | |
| Yes | 4.41 ± 1.27 | 0.05 | -0.25, 0.34 | | 0.09 | -0.23, 0.41 | |
| Accessing food from kitchen garden (<i>n</i> = 323) | | | | 0.016 | | | 0.006 |
| No | 4.34 ± 1.27 | - | - | | - | - | |
| Yes | 4.86 ± 1.24 | 0.58 | 0.11, 1.0 | | 0.68 | 0.20, 1.2 | |
| Accessing food from domesticated animals (<i>n</i> = 323) | | | | 0.019 | | | 0.003 |
| No | 4.52 ± 1.34 | - | - | | - | - | |
| Yes | 4.15 ± 1.12 | -0.33 | -0.61, -0.06 | | -0.46 | -0.76, -0.16 | |
| Accessing food from forest/open fields (<i>n</i> = 323) | | | | 0.12 | | | 0.016 |
| No | 4.37 ± 1.27 | - | - | | - | - | |
| Yes | 4.88 ± 1.46 | 0.69 | -0.18, 1.5 | | 1.2 | 0.22, 2.1 | |
| Accessing food from water source (pond, river, and sea) (<i>n</i> = 323) | | | | 0.55 | | | 0.2 |
| No | 4.39 ± 1.27 | - | - | | - | - | |
| Yes | 3.67 ± 0.58 | -0.43 | -1.8, 0.97 | | -0.9 | -2.4, 0.60 | |
| Accessing food from local market (<i>n</i> = 323) | | | | 0.58 | | | 0.5 |
| No | 4.50 ± 1.29 | - | - | | - | - | |
| Yes | 4.39 ± 1.27 | -0.35 | -1.6, 0.88 | | -0.39 | -1.6, 0.82 | |
| Accessing food from government food programs (<i>n</i> = 323) | | | | >0.99 | | | >0.9 |
| No | 4.50 ± 1.05 | - | - | | - | - | |
| Yes | 4.38 ± 1.28 | 0 | -1.0, 0.99 | | 0 | -0.99, 0.99 | |
| Accessing food from their friends, family, and community (<i>n</i> = 323) | | | | 0.89 | | | >0.9 |
| No | 4.39 ± 1.28 | - | - | | - | - | |
| Yes | 4.50 ± 0.58 | 0.09 | -1.1, 1.3 | | -0.02 | -1.3, 1.2 | |

¹SD, standard deviation.

²CI, confidence interval. *p*<0.05 values are highlighted in bold.

domains in isolation. The use of standardized tools, such as the Food Insecurity Experience Scale and the Minimum Dietary Diversity for Women, improved the methodological aspect. Finally, the study aligns with current policy discussions on public food programs, making the findings useful for improving these programs and designing food system interventions in similar rural settings for enhancing food security and dietary diversity in rural

communities. However, because the study relied on self-reported information, responses may have been influenced by what participants felt was expected. The dietary intake was assessed based on food items consumed on the previous day, which may not fully represent habitual dietary patterns and is subject to recall and reporting bias. Finally, since the study was conducted in only one district, the representativeness of the findings may be limited.

Data availability statement

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

Ethics statement

The studies involving humans were approved by Ethical approval was taken from the Institutional Ethics Committee at the George Institute for Global Health, Delhi, India and Imperial College, London. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

VS: Writing – original draft, Methodology, Writing – review and editing, Formal analysis, Supervision, Project administration, Data curation. AR: Formal analysis, Software, Writing – review and editing. SK: Writing – review and editing, Project administration, Methodology, Supervision, Data curation. AD: Methodology, Supervision, Formal analysis, Project administration, Data curation, Writing – review and editing. SG-J: Writing – review and editing, Project administration, Methodology, Supervision, Conceptualization, Data curation.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This research was funded by the NIHR (Grant Number: NIHR203247) using UK international development funding from the UK Government to support global health research.

Acknowledgments

We would like to express our sincere gratitude to the village leaders and community members in the study villages for their consent and active participation in the study. We also extend our appreciation to the field investigators who conducted the data collection of the survey. We

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are grateful to the project officers and field supervisors for their vital contributions in securing permissions, organizing the survey process, and providing translation support to enable smooth data collection.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2026.1735546/full#supplementary-material>

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