RESEARCH ARTICLE

Seasonal variations in household food security and consumption affect women's nutritional status in rural South Ethiopia

Bethelhem Mezgebe *, **Taye Gari, Mehretu Belayneh, Bernt Lindtjørn**

School of Public Health, College of Medicine and Health Sciences, Hawassa University, Hawassa, Ethiopia

* bethelhem_mezgebe@yahoo.com

Abstract

Food availability varies seasonally in most rural areas of developing nations, especially in areas affected by drought and climate change, with women being one of the most vulnerable groups. This study aimed to assess the effect of seasonal variation in household food security, adequate dietary diversity, food consumption, and wealth on the nutritional status of women of reproductive age in a rural community in South Ethiopia. Further, the study aimed at identifying associated factors with women's nutrition status. An open cohort study was conducted from June 2021 to June 2022, with follow-up visits every three months. Anthropometric measurements were carried out along with interviews. Data were analyzed using STATA version 15. Multilevel, multiple linear regressions were employed. Findings revealed that women's average body mass index (BMI) was 20.4 kg/m^2 (95% CI: 20.4–20.5). The highest (20.6 kg/m^2, 95% CI: 20.5–20.8) was observed in December, while the lowest (20.2 kg/m^2, 95% CI: 20–20.3) occurred in September. During the main postharvest period in December, the household food insecurity score was the lowest (median: 4, Inter quartile range (IQR): 0–9), while the household dietary diversity score (median: 6, IQR: 5–7), and the household food consumption score were the highest (median: 50.5, IQR: 44–70). Factors such as household food security, food consumption, previous season BMI, age, marital status, and membership in safety net programs were identified as determinants of women's BMI. The study showed the vulnerability of women in drought-prone areas to seasonal undernutrition. We recommend collaborative work among stakeholders to ensure sustainable food access and minimize seasonal food shortages' effect on women's nutrition and overall well-being.

Introduction

Farmers in low-income countries often rely on rain-fed agriculture, which is affected by seasonal and weather variability [1, 2]. This can lead to low and insufficient agricultural production for year-round consumption, resulting in periodic food scarcity, as shown in countries such as Burkina Faso, Ghana, Bangladesh, and Ethiopia [3–6]. Seasonal food shortages can also result in unstable household wealth and changing household food security [7–11], often affecting women's nutritional status [12–14].

The effect of seasonal food shortages on women's nutrition can be influenced by other factors such as workload, illness, culture, and reproductive responsibilities. Women usually work from dawn to dusk throughout the year on household chores, social obligations, paid labor, and substantial agricultural tasks during peak seasons [15, 16]. This heavy workload and inadequate food during lean periods can lead to an energy imbalance and undernutrition [17–20].

Illness is the other contributing factor to undernutrition, creating a vicious cycle [21]. Illness results in a loss of appetite, diminished nutrient absorption, and increased energy expenditure, all collectively contributing to undernutrition [22]. Undernutrition, in turn, can increase the incidence and severity of illnesses [23]. This can negatively influence household wealth by limiting women's productivity and increasing healthcare expenditure [24]. Studies in Ethiopia showed that intestinal parasitic infestation [25], anemia [26], malaria, and other infectious diseases can predict women's undernutrition. Limited decision-making power, a lack of money for treatment, and a lack of access to quality healthcare exacerbate the impact of illness on women's nutritional status [27, 28].

Culture can impact women's undernutrition by influencing the amount and quality of food they eat [29]. Pregnancy and breastfeeding increase nutritional needs, but studies show women in several countries often don't meet these recommendations, especially during periods of food shortages [8, 13, 30–32]. Focusing on women's nutrition is essential because they are vital to household food security since they are frequently involved in food production, purchasing, preparation, preservation, and allocation [33]. Furthermore, women often invest their income to improve the health and education of their children [19]. Therefore, improving women's nutrition is about her and the whole family's well-being.

Previous research in Nepal, Madagascar, and Ethiopia demonstrated the existence of seasonal variation in household food security, dietary diversity, and food consumption [13, 34–36]. However, the effect of these variations on the nutritional status of women of reproductive age group has yet to be adequately investigated. Many nutrition-related studies in Ethiopia and other low-income countries usually focus on pregnant women or mothers with children under the age of five, excluding women who are not yet mothers or are unable to conceive [37–40]. It is essential to recognize that assessing and improving women's nutrition extends beyond reproductive responsibilities. In Africa, women make up nearly 40% of the agricultural labor force [41], highlighting their significant contribution to the economy and emphasizing the importance of their well-being.

In our study, we conducted a more comprehensive assessment of the wealth index compared to the usual practice of measuring it only once. Instead, we measured it three times within a year to capture its temporal variation. Additionally, we considered the impact of women's previous BMI on their current BMI.

This study aimed to assess the effect of seasonal variation in household food security, adequate dietary diversity, food consumption, and wealth status on the nutritional status of women of reproductive age in a rural community in South Ethiopia and identify associated factors with women's nutritional status. To achieve these objectives, we tested the hypothesis that women's body mass index remains unchanged regardless of seasonal variations in household food security, consumption, dietary diversity, and wealth.

Methods and materials

Study area description, food production, and food availability

An open cohort study was conducted in the Boricha and Bilate Zuria districts in the Sidama National Regional State from June 2021 to June 2022, with follow-up visits every three months.

The Sidama Region has 30 districts and 636 *kebeles* (the smallest administrative unit in Ethiopia). Bilate Zuria and Boricha are drought-prone districts with 30 rural and two urban

kebeles. In 2022, the population size in these two districts was estimated to be 282,002, with 142,214 females. The annual birth rate was 22.8/1000 population, and women of reproductive age constitute 23.3% of the population. One primary hospital, eight health centers, and 30 health posts are governmental health institutions that provide health services to the population in the two districts [42].

The districts have a bimodal rainfall pattern; the main is *Belg*, which lasts from March to May, and the other rainy season, *Kiremt*, lasts from June to the end of September. Despite the presence of Bilate River in Bilate Zuria, both districts experience water scarcity, particularly during dry seasons [43].

The area has two harvesting times; the first harvest usually begins in August for short-cycle crops like potatoes, sweet potatoes, pepper, and haricot beans. The second harvest time starts around October for long-cycle crops like maize [44]. Enset (*Ensete ventricosum*), which takes 5 to 7 years to mature, is a resilient food source during lean periods [45]. Kale and sugarcane usually grow throughout the year. Some residences cultivate perennial crops like coffee, khat (*Catha edulis*), banana, and avocado. Coffee, khat, sugarcane, and paper are cash crops in the area.

Boricha and Bilate Zuria districts are food-insecure areas. The food shortage gradually improves with the first harvest as household food stocks replenish and mini corn (unripe corn) bridges the food deficit until the second harvest. Food stocks reach their peak during the second harvest [46]. However, in March, the food stocks usually deplete, and household food availability declines.

Food insecurity is deeply rooted and has multiple underlying causes in the area. Despite efforts to improve livelihoods, household food insecurity remains a persistent problem [47, 48]. Population density, land scarcity, limited crop diversity, traditional farming methods, and climate change contribute to decreased crop and livestock production, exacerbating household food insecurity [49–51].

Furthermore, the COVID-19 pandemic, national instability due to the civil war and local disputes have added to the challenges faced by the residents. These conditions have led to price inflation for fertilizers, seeds, and food, worsening the already vulnerable situation.

Ethical consideration

The Institutional Review Board of Hawassa University provided ethical clearance for the current study, conducted under the "Co-producing Gender-responsive Climate Services for Enhanced Food and Nutrition Security and Health in Ethiopia and Tanzania (COGENT) project." The project team obtained the first clearance on May 20, 2021(reference number IRB/ 181/13). Subsequently, a second clearance was obtained specifically for assessing women's nutritional status, illness assessment, and level of physical activity on September 7, 2021 (reference number IRB/275/13). Additionally, the project team acquired the necessary permission letters from the Regional Health Bureau and district health offices.

Written informed consent was obtained directly from participants who were 18 years old and above. In the case of adolescents below the age of 18, written consent was obtained from their parents or legal guardians. Throughout the study, strict confidentiality measures were implemented, ensuring that all information remained confidential. Personal identifiers were not used during the data analysis and data-sharing processes.

Data collection procedure

The study included households that had previously participated in a study conducted in 2017 [34]. To select the participants, a multistage sampling technique was employed. From the 30

rural *kebeles* in the districts, nine *kebeles* were randomly chosen. Subsequently, a total of 910 households were selected using cluster sampling. All eligible girls and women between the ages of 15 and 49 from the selected households were included in the study, except those who were seriously ill, paralyzed, deformed or belonged to families experiencing grief or festivity during the data collection period.

The sample size was calculated using OpenEpi version 3.03 (Open Source Epidemiologic Statistics for Public Health; www.OpenEpi.com). The sample size for the study was calculated based on the seasonal variation of women's BMI. A sample size of 904 women was determined using assumptions from a previous cohort study conducted in the eastern part of Ethiopia [14]. In that study, the percentage of mothers with a BMI less than 18.5 kg/m^2 during the pre-harvest season was 54.7%, and the percentage during the post-harvest period was 41.7%. A confidence level of 95% and a power of 80% were considered, with a ratio of unexposed to exposed individuals set at 1:1. Considering a design effect of 1.5 and assuming a 20% non-response rate; the final sample size was estimated to be 904 women. However, to minimize the effect of mobility and non-respondent rate we include all eligible (1,089 women) in the selected households.

Outcome variables

The outcome variable was body mass index (BMI). Body weight was measured using a digital *SECA* scale (SECA GmbH, Germany) with a precision of 0.1 kg. The weight measurements were conducted using the following procedure: Before data collection, we verified the accuracy of the weight scales using an object with a known weight. Data collectors ensured the scale reading was exactly at zero ahead of any measurement, and the measurements were taken on a flat surface. The individuals being weighed wore lightweight clothes and stood barefoot.

Height was measured with a standard stadiometer (SECA 217, GmbH, and Study Germany) to the nearest 0.1 cm. The participants stood upright, facing forward, with their heads and feet bare. They positioned themselves with their arms hanging at their sides, feet together, and ensuring contact between their heels, buttocks, shoulder blades, and head with the vertical surface of the stadiometer.

Predictor variables. Household level predictors were the socio-demographic status of the household head (marital status, educational status, and occupation), family size, household food security, household dietary diversity, household food consumption, household wealth index, and membership in a productive safety net program. Individual level factors were socio-demographic characteristics of the women (age, marital status, educational status, and occupation) and previous season BMI.

Food consumption score. Household food consumption was evaluated using a food frequency questionnaire comprising 12 food groups [52]. The questionnaire assessed the frequency at which households consumed specific food groups. Respondents were provided with eight options to recall the frequency of consumption. 1: once/week, 2: twice a week, 3: 3 times a week, 4: 4 times a week 5: 2 or more times a month 6: once a month 7: yearly 8: never

To calculate the food consumption score, the weekly consumption of each food group was weighted based on its nutrient density. The weighting scheme was as follows: cereals and roots were combined as main staples and assigned a weight of 2, vegetables weighed 1, fruits had a weight of 1, meat, fish, eggs, and milk had a weight of 4, pulses weighted 3, sweets weighted 0.5, fats weighted 0.5, and condiments weighted 0 [52]. The weight assigned to each food group was multiplied by the number of days that the food group was consumed in a week. These weighted scores for each food group were then summed together to obtain the total food consumption score. This score was classified based on the following cut points [52]:

Households with a food consumption score $< = 21$: poor food consumption;

Households with a food consumption score of 21.5 to 35: borderline food consumption; and,

Households with a food consumption score > 35: acceptable food consumption.

Household dietary diversity. A household dietary diversity score was calculated by summing up the number of food groups eaten in the house during the day and night before the date of data collection based on 24 hours of dietary recall for 12 food groups that include cereals, roots, or tubers; vegetables; fruits; meat or poultry; eggs; fish and seafood; pulses or nuts; milk and milk products; oil or fats; sugar or honey; and condiments or coffee [53]. Households with a household dietary diversity score $< = 3$ were considered to have low household dietary diversity, 4 to 6 medium household dietary diversity, and $> = 7$ high household dietary diversity.

Household Food Insecurity Access Scale (HFIAS). The Household Food Insecurity Access Scale (HFIAS), validated for use in the Ethiopian setting, was used to evaluate the seasonal household food insecurity variability [54–56]. It determined the household food insecurity condition four weeks before the study. It contains nine conditions, and each of them was scaled as never = 0, rarely = 1 (1 or 2 times a month), sometimes = 2 (3 to 10 times in a month), and often = 3 (more than ten times in a month). The household food insecurity score was calculated by adding the frequency for each of the nine conditions (0 to 3). The numeric outcome ranges from 0 to 27. The household food insecurity level was classified into food secure, mildly, moderately, and severely food insecure based on the indicator guide mentioned above [54–56].

Meal frequency. To assess meal frequency, we utilized a 24-hour dietary recall questionnaire. During data collection, participants were asked yes/no questions regarding the types of meals they had consumed on the previous day. Based on their responses, meal frequency was valued as 0: if nothing had been eaten, 1 for one meal/day, 2 for two meals/day, and 3 for three meals or more /day. They were also asked about the type of meal they had eaten in the past 24hours.

Wealth index. Economic status was assessed three times: in June 2021, December 2021, and June 2022. The wealth index was constructed using principal component analysis. Initially, the factors analysis included the following 15 asset-assessing variables: the size of farming land, livestock ownership, electricity, mobile telephone, chair, bed with cotton matters, kerosene-based lamp, type of floor, type of roof, type of wall, place of cooking, telephone expenditure per month, monthly i*dir* (traditional cooperation and the supporting system usually during grief) expense, monthly saving, and participation in *equib* (traditional saving association). The principal component analysis excluded variables with sample adequacy < 0.5, communality < 0.5, and complex structure. The correlation matrix for the variables in the PCAs contains two or more correlations of 0.30 or greater. The final component analysis included the following five variables: mobile phone, type of roof, type of floor, type of wall, and telephone expense per month. The overall sampling adequacy Kaiser-Meyer-Olkin (KMO) test was > 0.50 (0.65), and the P-value of Bartlett's Test of Sphericity was < 0.001 [57].

The data collection tool was prepared in English and translated into *Sidaamo Afoo*. It contains questions regarding socio-demographic characteristics, housing conditions, other asset-assessing questions, household food insecurity, 24-hour dietary recall, and food frequency. Data was obtained through face-to-face interviews and anthropometric measurements. Eighteen data collectors, two from each *kebele*, were involved in data collection. All of them had completed tenth grade or more and were fluent speakers of the local *Sidaamo Afoo* language.

Pre-tests were done in the Qorangoge *kebele* found out of the selected *kebeles*. Training was provided for data collectors and supervisors on the questionnaire's contents and how to take anthropometric measurements. To improve the data accuracy, the height of the women was

taken in two seasons, in September 2021 and December 2021, and the average height was taken for BMI calculation. If there were discrepancies between the height measurements, a third measurement was taken. All data collection was closely monitored and supervised.

Data were collected four times in addition to the baseline data: in September and December (post-harvest time) and in March and June (pre-harvest time). Socio-demographic status was assessed only once on baseline (June 2021); household asset (3,133 observations) was collected three times (June 2021, December 2021, and June 2022); household food security (5,238 observations) and household dietary diversity (5,225 observations) were assessed five times throughout the data collection time; food consumption (4,185 observations) and women's anthropometry (3,911 observations) were measured four times: September 2021, December 2021, March 2022, and June 2022.

At the baseline, women from 910 households were recruited. In the final analysis, 1,089 women from 894 households were included. It was observed that 169 households had two or more women participating in the study. At the beginning of the study, there were 1,055 women, and an additional 34 participants were enrolled in September and December. Consequently, a total of 1,089 women participated in the study. On average, 1,050 women of reproductive age group were followed up for 12 months with a follow-up visit every three months (Fig 1).

Data processing and analysis

The questionnaires were checked and edited during data collection at the end of each day. The data was entered into EpiData version 3.1 (EpiData Classic, Http://www.epidata.dk) and analysed using SPSS Version 25 (IBM Corp, Armonk, NY) and STATA Version 15 (Stata Corp, Texas, USA).

Descriptive statistics was performed to explore the data, identify outliers, and understand the data's nature. Multilevel mixed-effect linear regression was conducted to understand the *kebele*, *Gout* (a subdivision of *kebele*), and household-level variability [58]. In our analysis, the clustering effect at the empty model's household, *Gout*, and *kebele* levels was 65.4%, 3.6%, and 2%, respectively. However, our final model showed no household-level effect, so the analysis was performed without controlling these potential clustering effects. Despite the absence of clustering, we employed multilevel mixed-effect linear regression to address the issue of dependency and unbalanced measurements.

Multicollinearity was checked using variance inflation factor (VIF), normality was assessed through histograms and normality curves, and linearity was examined using a Q-Q plot. Both household and individual level variables with a P-value of < 0.25 in the univariate analysis were included in the multivariate analysis. Subsequently, a model was constructed, and the model with the lowest Akaike's information criterion (AIC) value of 5,217 was chosen as the final model. In the multivariable analysis, variables with a P-value of < 0.05 were considered the final predictor of women's BMI.

Results

Baseline socio-demographic characteristics of participants

Adolescents 15 to 19 years old contribute to 135/1089 (12.4%) of the participants.

The average family size (SD) was 5.6 (1.7) persons. The mean age of the women (SD) was 28.9 (7.6) years. Nearly 80% of the respondents (865/1089) were married. Most women, 71.5% (779/1,089), were engaged in farming as their occupation. Among the participants, 57.7% (628/1089) had not attended formal education. Almost all residents, 99.5% (1083/1089), belonged to the Sidama ethnicity. Additionally, 85.1% (927 out of 1089) of the participants were Protestant.
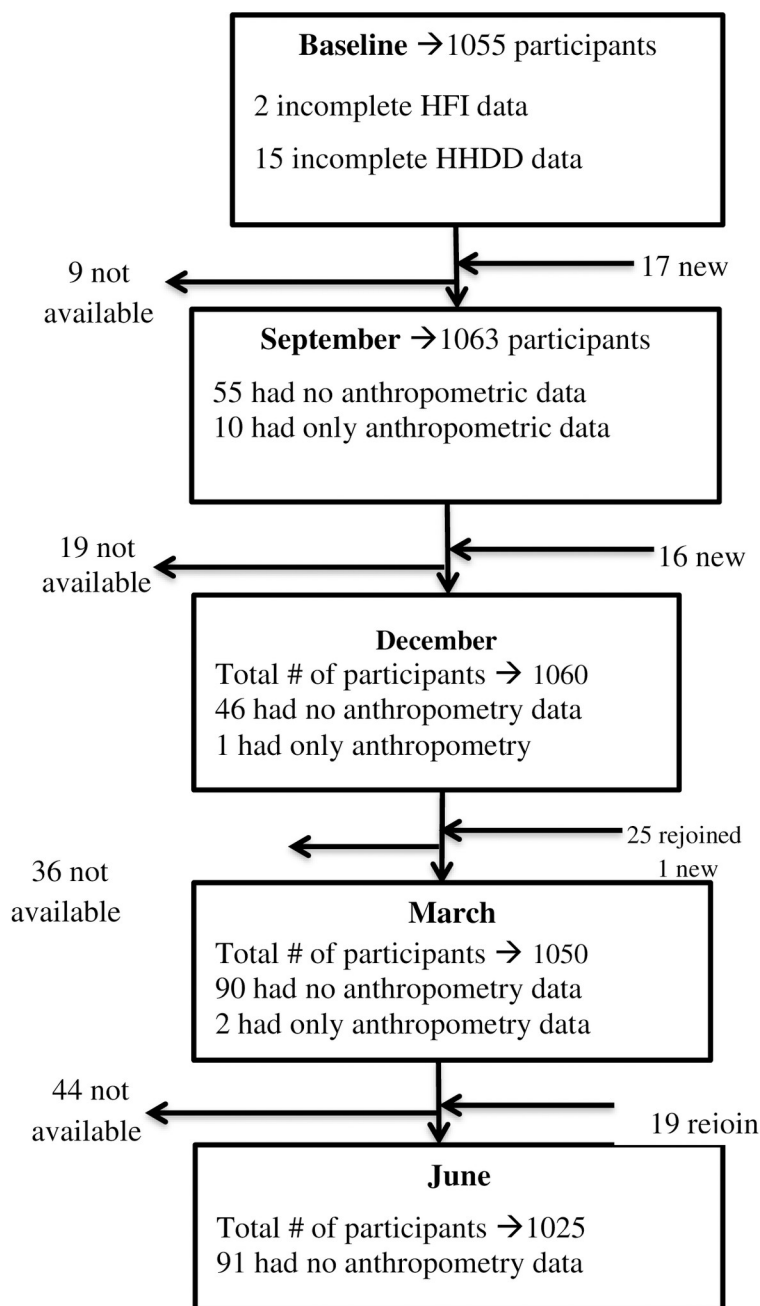
Fig 1. Flow chart showing the dynamics of study participants. Flowchart of Study Participants Dynamics. This figure illustrates the flow of study participants across the different phases of the research. It conveys information about the number of participants at each stage, as well as the dynamic movement of individuals in and out of the study. The figure also showed the missing data of main variables in each season. The abbreviations used are: HFI: Household Food Insecurity, HHDD: Household Dietary Diversity.

Household food security, dietary diversity, meal type, and food consumption

Of 5,238 observations, 15.4% (808 observations) were from food-secured households, while 61% (3,194 observations) were from severely food-insecure households. Regarding the proportion of women from food-secured households, the highest proportion was observed in

Table 1. Seasonal variation of household food security, dietary diversity, food consumption and meal type among women of reproductive age groups in South Ethiopia: June 2021 to June 2022.

Household food security category	June 2021 N = 1053 n (%)	September N = 1053 n (%)	December N = 1059 n (%)	March N = 1048 n (%)	June 2022 N = 1025 n (%)	Over all observation N = 5238
Food secure	133 (12.6)	131 (12)	347 (32.8)	130 (12.4)	67 (6.5)	808 (15.4)
Mildly insecure	42 (4.0)	67 (6.4)	195(18.4)	139 (13.4)	82 (8)	525 (10.2)
Moderately insecure	70 (6.7)	141 (13.6)	185 (17.5)	147 (14)	168 (16.4)	711 (13.6)
Severely insecure	808 (76.7)	714 (67.9)	332 (31.4)	632 (60.3)	708 (69.1)	3194 (61)
Household Dietary diversity	**N = 1040**	**N = 1053**	**N = 1059**	**N = 1048**	**N = 1025**	**N = 5225**
Low	123 (11.8)	217 (20.6)	54 (5.1)	95 (9.1)	57 (5.6)	546 (10.5)
Medium	704 (67.7)	725 (68.9)	721 (68.1)	779 (74.3)	854 (83.3)	3783 (72.4)
High	213 (20.5)	111 (10.5)	284 (26.8)	174 (16.6)	114 (11.1)	896 (17.2)
Meal type per day	**N = 1040**	**N = 1053**	**N = 1059**	**N = 1048**	**N = 1025**	**N = 5225**
> = 3 meals	526 (50.6)	564 (53.6)	851 (80.4)	711 (67.8)	634 (61.9)	3286 (62.9)
Breakfast and Dinner	382 (36.7)	373 (35.4)	185 (17.5)	262 (25)	357 (34.8)	1559 (29.8)
Lunch and Dinner	100 (9.6)	59 (5.6)	17 (1.6)	63 (6.0)	29 (2.8)	268 (5.1)
Breakfast and lunch	6 (0.6)	57 (5.4)	5 (0.5)	12 (1.1)	2 (0.2)	82 (1.6)
< 2meals	26 (2.4)	0 (0.0)	1 (0.1)	0 (0.0)	3 (0.3)	30 (0.6)
Food consumption		**N = 1053**	**N = 1059**	**N = 1048**	**N = 1025**	**N = 4185**
Poor		81 (7.7)	27 (2.5)	28 (2.7)	15 (1.5)	151 (3.6)
Border line		332 (31.5)	89 (8.4)	159 (15.2)	363 (35.4)	943 (22.5)
Acceptable		640 (60.8)	943 (89.1)	861 (82.1)	647 (63.1)	3091 (73.9)

https://doi.org/10.1371/journal.pgph.0003294.t001

December, accounting for 32.8% (347 out of 1,059 observations), while the lowest was observed in June 2022, with only 6.5% (67 out of 1,025 observations); see Table 1.

Most households had a medium dietary diversity of 72.4% (3,783/5,225 measurements). In December, the highest percentage of households with a high dietary diversity score was 26.8% (284/1059). Conversely, the lowest, 10.5% (111/1059), was observed in September; see Table 1.

About one-third of the study participants, 37.1% (1939/5225 measurements), reported having two or fewer meals daily. At the baseline, around half of the women (49.4%; 514/1040) skipped one or more meals daily, the highest of all observed seasons. Lunch was the most frequently missed meal (29.8%; 1559/5225); see Table 1.

From all observations, 151 of 4,185 measurements (3.6%) had poor household food consumption. The percentage of households with acceptable food consumption was higher in December at 89.1% (943/1,059) and March at 82.1% (861/1048), compared with September at 60.8% (640/1,053) and June at 63.1% (647/1025); see Table 1.

The household food insecurity score (HFIASS) was the lowest in December (median: 4, IQR (interquartile range): 0–9) and the highest in June (median: 11, IQR: 7–16). The household dietary diversity score was nearly similar during the study periods, with a slight increment in December (median: 6, IQR: 5–7). On the other hand, the food consumption score was highest in December (median: 50.5, IQR: 44–70) and lowest in September (median: 39.5, IQR: 26–53) (Fig 2).

Wealth index

The median (IQR) wealth index for all observations was 2,211 (900.5, 2,211). From all observations, nearly half of the households (52.1%: 1,635/3,138) were poor. The proportion of women from extremely poor households was the highest in June 2,022 (18.8%: 193/1027). At baseline, the proportion of very poor households (26.2%: 276/1,053) was the highest, while the proportion of women from rich households (11.4%: 120/1053) was the lowest, see Table 2.
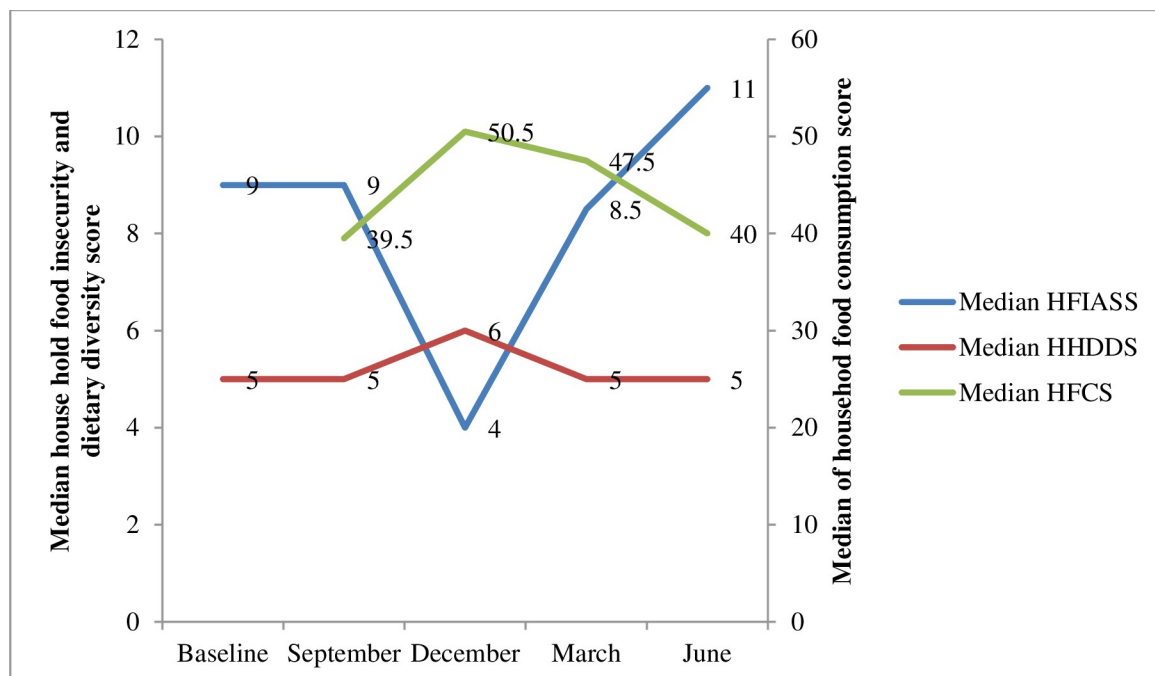
Fig 2. Seasonal variation in the median score of household food insecurity, dietary diversity, and food consumption of women. Seasonal variation in Household Food Access. This figure illustrates the seasonal variations in key measures of household food access. Specifically, it plots the median values and interquartile ranges for: • HFIASS: Household Food Insecurity Access Scale Score.• HDDS: Household Dietary Diversity Score.• HFCS: Household Food Consumption Score.

BMI of women

The mean BMI (95% CI) for women was 20.4 kg/m^2 (20.4, 20.5), with the highest BMI observed in the age group of 20–24 years at 20.9 kg/m^2 (20.7, 21.1). Among the different marital status groups, single women had the highest mean BMI of 20.7 kg/m^2 (20.5, 20.9). On the other hand, women with no formal education had the lowest mean BMI of 20.2 kg/m^2 (20.1, 20.3); See Table 3.

The average BMI of December 20.6 kg/m^2 (95% CI: 20.5, 20.8) and March 20.6 kg/m^2 (95% CI: 20.4, 20.7) was significantly higher than the average BMI of September 20.2 kg/m^2 (95% CI: 20.0, 20.3) and June 20.3 kg/m^2 (95% CI: 20.2, 20.5); See Fig 3.

Predictors of women's nutritional status

A multilevel linear regression was employed to identify factors associated with women's BMI. In the bivariate analysis, the following household-level factors showed a P-value of < 0.25: household food security, dietary diversity, food consumption, and membership in a productive safety net program. Even if the wealth index had a higher P-value, we included it in the final

Table 2. Household wealth status of women of reproductive age group in June 2021, December 2021, and June 2022, South Ethiopia.

Household wealth	June 2021 N = 1053 n (%)	December N = 1058 n (%)	June 2022 N = 1027 n (%)	Overall N = 3138 n (%)
Extremely poor	138 (13.1)	146 (13.5)	193 (18.8)	477 (15.2)
Very poor	276 (26.2)	184 (17.4)	148 (14.4)	608 (19.4)
Poor	519 (49.3)	579 (54.7)	537 (52.3)	1635 (52.1)
Rich	120 (11.3)	149 (14.5)	149 (14.5)	418 (13.3)

Table 3. Mean BMI of women 15 to 49 years old in south Ethiopia: September 2021 to June 2022.

Variable	Mean BMI (95% CI)	SD
Age in year		
15–19	20.4 (20.2, 20.6)	2.0
20–24	20.9 (20.7, 21.1)	2.2
25–29	20.5 (20.4, 20.6)	2.1
30–34	20.3 (20.2, 20.5)	2.3
35–39	20.4 (20.2, 20.5)	2.3
> = 40	20.2 (19.9, 20.4)	2.5
Relation Ship		
Household head	20.3 (19.9, 20.8)	2.3
Wife	20.4 (20.3, 20.5)	2.2
Child	20.7 (20.5, 20.9)	2.2
Other (Maid and relatives)	19.8 (16.6, 23.1)	2.6
Marital status		
Married	20.4 (20.3, 20.5)	2.2
Single	20.7 (20.5, 20.9)	2.2
others (Divorced and Widowed)	20.2 (19.8, 20.7)	2.3
Educational status		
Couldn't read and write	20.2 (20.1, 20.3)	2.3
Read and write	20.4 (20.1, 20.7)	2.0
Primary	20.7 (20.6, 20.9)	2.2
Secondary and above	20.7 (20.4, 20.9)	2.2
Occupational status		
Farmer	20.3 (20.2, 20.4)	2.2
Student	20.8 (20.7, 21.0)	2.2
Trader	21.0 (20.7, 21.3)	2.6
Other (employed, dependent, daily labourer)	19.9 (19.5, 20.3)	2.2
Membership of safety net program		
Yes	20.3 (20.1, 20.5)	2.0
No	20.5 (20.4, 20.5)	2.3

model by considering its importance. On the other hand, all individual-level factors had a P-value of < 0.25. However, the final model did not include occupational status because its inclusion in the multivariable analysis increased the Akaike Information Criterion (AIC) from 5217 to 5222. Therefore, the determinant factors of women's BMI identified in the final model were household food insecurity score, household food consumption score, previous season BMI, age, educational status, marital status, and productive safety net program membership.

The analysis showed that as age increased by one year, women's BMI increased by β coefficient of 0.03 (95% CI: 0.02, 0.04). Household food insecurity score had an inverse relation with the BMI of women with β coefficient of -0.02 (95% CI: -0.03, -0.01), while the household food consumption score had a positive relation of 0.01 (95% CI: 0.01–0.02). Furthermore, the study found that women with a lower BMI in the previous season were likelier to have a lower BMI in the current season, as indicated by a β coefficient of 0.91 (95% CI: 0.89, 0.93). Unmarried women had higher BMI than married women, with a β coefficient of 0.57 (95% CI: 0.36, 0.77). Additionally, women who were not beneficiaries of the safety net program had higher BMIs than program beneficiaries, who had 0.38 (95% CI: 0.18–0.57); see Table 4.
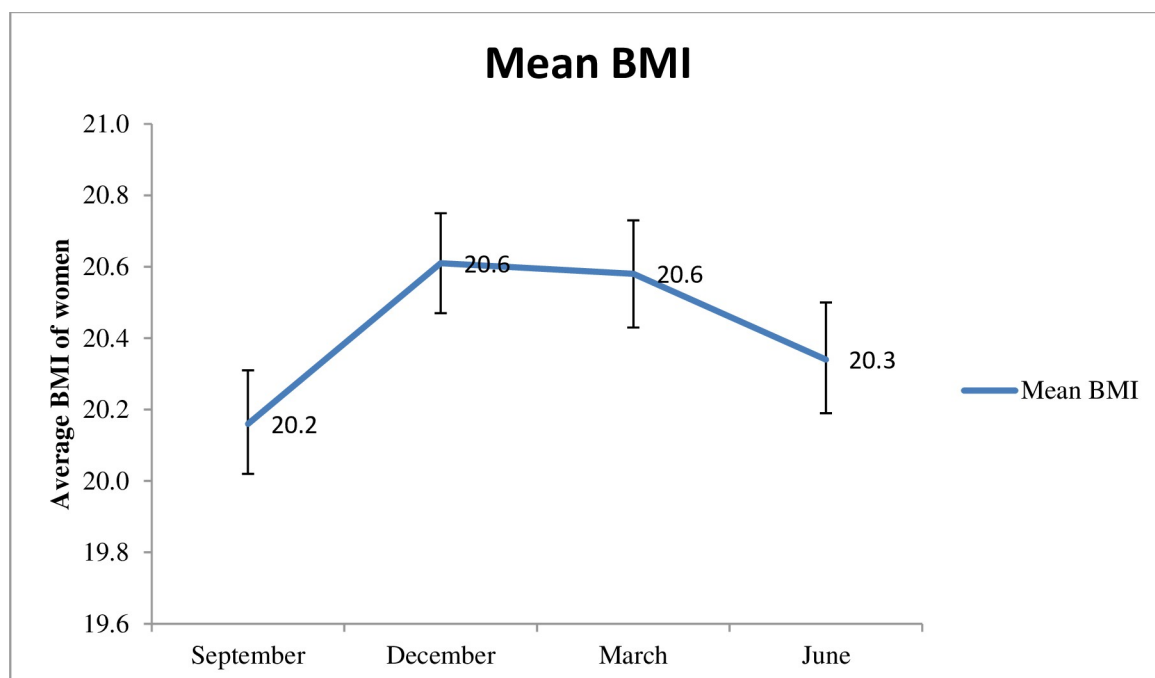
Fig 3. Comparison of women's BMI along different seasons, from September 2021 to June 2022, South Ethiopia. Seasonal variation in Women's Body Mass Index. This figure illustrates the seasonal variation in the average body mass index of women in the study population. The abbreviations used is BMI: Body Mass Index.

https://doi.org/10.1371/journal.pgph.0003294.g003

Discussion

This study revealed the seasonal variation in household food access. Contrary to traditional assumptions, the study found that food scarcity occurred during the lean period in June, a month traditionally considered part of the food-plenty season in September. This suggests that

Table 4. Predictors of BMI of women of reproductive age group from September 2021 to June 2022, South Ethiopia.

Variables	β coefficient	95% CI	P-value
Age	0.03	0.02–0.04	<0.001*
Educational status	-0.01	-0.03, 0.02	0.578
Household food insecurity score	-0.02	-0.03–0.01	0.004*
Household dietary diversity score	0.03	-0.02–0.09	0.224
Food consumption score	0.01	0.01–0.02	<0.001*
Wealth index	0.00002	-0.0001–0.0001	0.595
Previous BMI	0.91	0.89–0.93	<0.001*
Marital status			
Married	1		
Single	0.57	0.36–0.77	<0.001*
others (Divorced and Widowed)	-0.14	0.47–0.2	0.416
Safety net			
Yes	1		
No	0.38	0.18–0.57	<0.001*

* P- Value < 0.05

https://doi.org/10.1371/journal.pgph.0003294.t004

the timing and duration of food shortages are unpredictable, underscored by the need to understand food accessibility dynamics.

The study also showed a relative improvement in women's average BMI during the season of better food access, indicating their higher vulnerability to seasonal undernutrition. Lower BMI was observed among married women, Productive Safety Net Program (PSNP) beneficiaries, and those with lower BMI in the previous season, suggesting these groups face compounded challenges. However, in this study, seasonal change in household wealth was not a predictor of women's BMI.

These findings suggest the need to consider the potential influence of localized weather patterns and the importance of examining seasonal food shortages within the broader climatic context. The development of climate resilience initiatives might help ensure year-round household food accessibility. Additionally, comprehensive interventions to better serve the specific needs of the most susceptible women to seasonal undernutrition are required to make a tangible difference in safeguarding their health and well-being.

The study's methodological approach was a key strength; an open cohort design allowed us to capture the dynamic, time-dependent relationships between food access, household wealth, and women's nutritional status. This longitudinal perspective allowed the detection of trends and changes over time, a significant advancement from previous cross-sectional studies that provided only a static snapshot. The open cohort design also helped minimize loss to follow-up, enhancing the validity of the findings.

The main limitations of the study include the length of follow-up time, different kinds of biases, and residual confounders. In drought-prone areas like Boricha, the study period of one year may have limited the ability to map seasonal patterns fully. Secondly, there is a limitation regarding the BMI of adolescents in the last two seasons. Since height measurements were only taken during the first two consecutive seasons, the BMI of adolescents in later seasons may be higher than expected due to potential height changes within six months. This study might be susceptible to information bias, such as social desirability and recall bias. Moreover, other unmeasured factors could affect the findings, such as the impact of school feeding programs, deworming, parity, contraception use, and other variables that should have been accounted for in our study. Lastly, using an open cohort design restricts the establishment of causal relationships.

Despite the potential biases mentioned earlier, various efforts were undertaken to mitigate their impact on the study's validity. We tried to minimize the social desirability bias aroused by the potential over-reporting of food scarcity in anticipation of aid by clearly explaining the study's objectives to the respondents. Given that most dietary assessments relied on memory, there was a susceptibility to recall bias. To address this, we employed various strategies: we prompted respondents to recall their situations for household food security assessments and provided illustrative examples for each condition. Respondents were requested to list their food intake over the past 24 hours to minimize recall bias in household dietary diversity assessments. Furthermore, we managed recall bias in food consumption by restricting the duration of the food frequency analysis to a week. To mitigate information bias arising from inter- and intra-observer variability in anthropometric measurements, rigorous training sessions were conducted repeatedly. Despite the study's limitations, the sample size was sufficient for generalizing the findings to similar drought-prone areas.

In the current study, food availability was better in post-harvest than pre-harvest season, which aligns with findings in previous studies [9, 13, 59, 60]. A study conducted in the same area about five years ago showed that the prevalence of household food insecurity was higher in March than in September [34], contrary to the current study. The unexpected food shortage in September and better household food security in March might be related to the inadequate

and late onset of *Belg* rain for 2021 [44]. This might have postponed the harvest time, prolonged the lean period until September, and extended the food stock for longer. Alternatively, there could be unmeasured nutritional interventions, support, or aids that reduce the magnitude of household food insecurity in March [7]. The food accessibility in December and June followed the expected pattern.

The mean BMI is consistent with a study conducted in eastern Ethiopia [61] but slightly lower than other studies in Ethiopia [62–64]. The difference in average BMI in the later studies could be due to differences in the study target. The target groups in these studies were lactating women. The current study was also conducted in drought-prone areas, which could contribute to the lower average BMI. This relatively lower average BMI suggests the presence of potential nutritional deficiencies and associated health risks.

In our study, women's average BMI was higher during December and March, corresponding to seasons with relatively better food access. This observation aligns with previous studies demonstrating the positive impact of improved household food access on women's nutritional status [14, 35, 65].

Food-insecure households may not get adequate amounts and quality of food, predisposing them to undernutrition or overnutrition [66]. In this study, household food security and high food consumption scores were associated with better BMI, consistent with other study findings [36, 47, 67]. This study's mean BMI improved as age increased, which is consistent with previous studies [68, 69]. As women age increases, reproductive responsibilities also increase, possibly contributing to weight gain.

In the current study, unmarried women had a better BMI than married women, supported by a few studies [70, 71]. Most unmarried women were 15 to 19 years old and were primary school students, potentially receiving additional food from school feeding programs [72]. On the other hand, almost all married women were mothers, and food allocation was their responsibility. Therefore, during times of food shortage, they might prioritize their children [73]. This could be an additional explanation for the higher BMI among unmarried women in the current study. This suggests that mothers are more susceptible to seasonal undernutrition compared to women who are not mothers.

The Productive Safety Net Program (PSNP) is one of the social protection schemes in Ethiopia [74]. It aims to support vulnerable households by offering cash transfers or food assistance for half of the year, usually during food shortages. However, several challenges hinder the program's effectiveness, including inadequate cash transfers, delayed payments, and lack of sustainable effect [75]. Despite these challenges, the PSNP positively impacts household food security and helps to prevent asset loss during catastrophic shocks [48, 75, 76]. The current study indicated that the mean BMI of PSNP beneficiary women was lower than that of the non-beneficiaries, as shown by [61].

Contrary to this, other studies have shown that PSNP reduces childhood stunting and women's undernutrition [64, 77]. In the current study, the BMI of PSNP beneficiaries was lower than their counterparts in all seasons. This could suggest a pre-existing difference in average BMI between PSNP beneficiaries and non-beneficiaries. Therefore, further research is required to determine the effect of the PSNP on women's nutritional status. This finding indicates that the Safety Net program should reassess the adequacy of its support to its beneficiaries. Furthermore, it should be integrated with other interventions to enhance the program's effectiveness.

This study found that women's nutritional status in the previous season influences their nutritional status in the current season. This suggests that undernourished women will likely remain undernourished, regardless of some improvement in food availability.

Conclusion

Household food security, dietary diversity, and food consumption vary across seasons. These variations are accompanied by changes in women's BMI, highlighting their vulnerability to undernutrition during certain seasons. However, the patterns of variation are different from year to year and are influenced by the weather conditions. Any deviations from typical weather patterns can decrease crop productivity and food accessibility and subsequently impact the nutritional status of the women. In addition to food accessibility, age, marital status, productive safety net membership, and previous BMI were predictors of women's BMI.

Recommendation

To tackle seasonal food shortages and their disproportionate impact on women's nutrition, we recommend that policymakers integrate sustainable food access policies across sectors and develop gender-responsive social protection programs. Local governments should empower women through entrepreneurship, vocational training, financial services, and nutrition education. Researchers should explore options to minimize reliance on rain-fed agriculture and evaluate the effectiveness of social protection programs. Farmers should diversify their income sources by engaging in off-farm activities. Implementing these recommendations could improve the nutritional well-being of women and other vulnerable groups.

Supporting information

S1 Table. Socio-demographic characteristics of 15 to 49-year-old women in South Ethiopia, June 2021. This table provides the socio-demographic information of 1,089 women participants from 894 households. The data are presented as count (n) and percentage (%). The abbreviation "N" refers to the total number of participants.
(DOCX)

S2 Table. Socio-demographic characteristics of household heads, South Ethiopia, June 2021. This table presents the socio-demographic information of the household heads where the study participants reside. The data are presented as count (n) and percentage (%).
(DOCX)

Author Contributions

Conceptualization: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Data curation: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Formal analysis: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Funding acquisition: Bernt Lindtjørn.

Investigation: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Methodology: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Project administration: Taye Gari.

Resources: Taye Gari, Bernt Lindtjørn.

Software: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Supervision: Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Visualization: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Writing – original draft: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

Writing – review & editing: Bethelhem Mezgebe, Taye Gari, Mehretu Belayneh, Bernt Lindtjørn.

References

1. Tirado M.C., Crahay P., Hunnes D., Cohen M., Denton F., Lartey A. Climate change and nutrition in Africa: With a focus on Sub-Saharan Africa. SUNRAY, 2012.

2. Krishna Krishnamurthy P., Kirsty Lewis, Choularton Richard J. Climate impacts on food security and nutrition. WFP, Met office, 2012.

3. Arsenault Joanne E., Nikiema Laetitia, Allemand Pauline, Ayassou Kossiwavi A., Lanou Hermann, Moursi Mourad, et al. Seasonal differences in food and nutrient intakes among young children and their mothers in rural Burkina Faso. JOURNAL OF NUTRITIONAL SCIENCE. 2014; 3(55):1–9. https://doi.org/10.1017/jns.2014.53 PMID: 26101623

4. Abizari A-R, Azupogo F, Nagasu M, Creemers N, Brouwer ID. Seasonality affects dietary diversity of school-age children in northern Ghana. PloS one. 2017; 12(8). https://doi.org/10.1371/journal.pone.0183206 PMID: 28806418

5. Chris Hillbruner, and Rebecca Egan. Seasonality, household food security, and nutritional status in Dinajpur, Bangladesh. Food and Nutrition Bulletin. 2008; 29(3).

6. Sibhatu K, Qaim M. Rural food security, subsistence agriculture, and seasonality. PloS one. 2017;12. https://doi.org/10.1371/journal.pone.0186406 PMID: 29049329

7. Raihan Mohammad Jyoti Farzana Fahmida Dil, Sabiha Sultana, Saha Kuntal Kumar Haque Md Ahshanul, Rahman Ahmed Shafiqur, et al. Effect of Seasons on Household Food Insecurity in Bangladesh. Food and energy security. 2018.

8. Hanley-Cook GT, Argaw A, de Kok B, Toe LC, Dailey-Chwalibóg T, Ouédraogo M, et al. Seasonality and Day-to-Day Variability of Dietary Diversity: Longitudinal Study of Pregnant Women Enrolled in a Randomized Controlled Efficacy Trial in Rural Burkina Faso. The Journal of nutrition. 2022; 152 (9):2145–54. https://doi.org/10.1093/jn/nxac104 PMID: 35524695

9. Stevens B, Watt K, Brimbecombe J, Clough A, Judd J, Lindsay D. The role of seasonality on the diet and household food security of pregnant women living in rural Bangladesh: a cross-sectional study. Public health nutrition. 2017; 20(1):121–9. https://doi.org/10.1017/S136898001600183X PMID: 27573667

10. Hirvonen K, Taffesse AS, Worku Hassen I. Seasonality and household diets in Ethiopia. Public health nutrition. 2015; 19:1723–30. https://doi.org/10.1017/S1368980015003237 PMID: 26585676

11. Lázár AN, Adams H, Adger WN, Nicholls RJ. Modelling household well-being and poverty trajectories: An application to coastal Bangladesh. PloS one. 2020; 15(9):e0238621. https://doi.org/10.1371/journal.pone.0238621 PMID: 32886732

12. Savy M, Martin-Pre ´vel Y, Traissac P, Eymard-Duvernay S, Delpeuch F. Dietary diversity scores and nutritional status of women change during the seasonal food shortage in rural Burkina Faso. Journal of Nutrition 2006; 136:2625–32.

13. Saville NM, Cortina-Borja M, De Stavola BL, Pomeroy E, Marphatia A, Reid A, et al. Comprehensive analysis of the association of seasonal variability with maternal and neonatal nutrition in lowland Nepal. Public health nutrition. 2021; 25(7):1–16. https://doi.org/10.1017/S1368980021003633 PMID: 34420531

14. Roba KO'Connor T, Belachew T, O'Brien N. Seasonal variation in nutritional status and anemia among lactating mothers in two agro-ecological zones of rural Ethiopia: A longitudinal study. Nutrition. 2015; 31 (10): 1213–8. https://doi.org/10.1016/j.nut.2015.03.007 PMID: 26238533

15. Food and Agriculture Organization of the united nations (FAO). Addressing women's work burden Key issues, promising solutions and way forward. 2016.

16. Komatsu H, Malapit H, Balagamwala M. Gender effects of agricultural cropping work and nutrition status in Tanzania. PloS one. 2019; 14(9):e0222090. https://doi.org/10.1371/journal.pone.0222090 PMID: 31490988

17. Harun ME. Womens workload and their role in agricultural production in Ambo district, Ethiopia. Journal of Development and Agricultural Economics. 2014; 6:356–62. https://doi.org/10.5897/jdae2013.0546

18. Galfato Gabiso, Tesfaye Abebe, TeferTewodros. Women in Home garden Agro forestry system of Sidama, SNNPRS, Ethiopia Scholarly Journal of Agricultural Science 2015; 5(4):103–11.

19. Jabeen Salma, Haq Sanam, Jameel Arif, Hussain Abid, Asif Muhammad, Hwang Jinsoo, et al. "Impacts of Rural Women's Traditional Economic Activities on Household Economy: Changing Economic Contributions through Empowered Women in Rural Pakistan. Sustainability, MDPI. 2020; 12(7):1–23.

20. Ma. Elena Chiong-Javier. Health Consequences of Rural Women Productive Role in Agriculture in the Philippines and Other Developing Countries. Journal of International Women's Studies. 2009; 10(4).

21. Joffe Michael. Health, livelihoods, and nutrition in low-income rural systems. Food and Nutrition Bulletin. 2007; 28(2). https://doi.org/10.1177/15648265070282S202 PMID: 17658069

22. Maleta K. Undernutrition Malawi Med J. 2006; 18(4):189–205.

23. Militao EMA, Salvador EM, Uthman OA, Vinberg S, Macassa G. Food Insecurity and Health Outcomes Other than Malnutrition in Southern Africa: A Descriptive Systematic Review. International journal of environmental research and public health. 2022; 19(9). https://doi.org/10.3390/ijerph19095082 PMID: 35564477

24. John Ulimwengu. Farmers' health and agricultural productivity in rural Ethiopia AFJARE September 2009; 3(2).

25. Gemechu Kumera, Dereje Gedle, Animut Alebel, Fetuma Feyera, and Setegn Eshetie. Undernutrition and its association with socio-demographic, anemia and intestinal parasitic infection among pregnant women attending antenatal care at the University, Northwest Ethiopia. Maternal Health, Neonatology, and Perinatology. 2018; 4(18).

26. Andersen CT, Tadesse AW, Bromage S, Fekadu H, Hemler EC, Passarelli S, et al. Anemia Etiology in Ethiopia: Assessment of Nutritional, Infectious Disease, and Other Risk Factors in a Population-Based Cross-Sectional Survey of Women, Men, and Children. The Journal of nutrition. 2021; 152(2):501–12. https://doi.org/10.1093/jn/nxab366 PMID: 34647598

27. Todd P Lewis Margaret McConnell, Aryal Amit, Irimu Grace, Mehata Suresh, Mrisho Mwifadhi, et al. Health service quality in 2929 facilities in six low-income and middle-income countries: a positive deviance analysis. The Lancet Global health. 2023; 11(6). https://doi.org/10.1016/S2214-109X(23)00163-8 PMID: 37202022

28. Park J-E, Kibe P, Yeboah G, Oyebode O, Harris B, Ajisola MM, et al. Factors associated with accessing and utilisation of healthcare and provision of health services for residents of slums in low and middle-income countries: a scoping review of recent literature. BMJ open. 2022; 12(5):e055415. https://doi.org/10.1136/bmjopen-2021-055415 PMID: 35613790

29. Harris-Fry H, Shrestha N, Costello A, Saville NM. Determinants of intra-household food allocation between adults in South Asia–a systematic review. International journal for equity in health. 2017; 16 (1):107. https://doi.org/10.1186/s12939-017-0603-1 PMID: 28637477

30. French agency for food environmental and occupational health and safety (ANSES). Dietary guidelines for specific population groups. Children, pregnant & breastfeeding women and the elderly 2019 expert appraisal. 2019.

31. Lander RL, Hambidge KM, Westcott JE, Tejeda G, Diba TS, Mastiholi SC, et al. Pregnant Women in Four Low-Middle Income Countries Have a High Prevalence of Inadequate Dietary Intakes That Are Improved by Dietary Diversity. Nutrients. 2019; 11(7). https://doi.org/10.3390/nu11071560 PMID: 31295916

32. Zebenay Workneh Bitew, Alemu Ayinalem, Ermias Getaneh Ayele, Teshager Worku. Dietary diversity and practice of pregnant and lactating women in Ethiopia: A systematic review and meta-analysis. Food science and nutrition. 2021; 9:2686–702. https://doi.org/10.1002/fsn3.2228 PMID: 34026082

33. Naz Madiha, Izhar Ahmad Khan, Ashfaq Ahmad Maan, Shahbaz B. Rural women contribution in household food security in agrarian communities: a cross-sectional study of rural areas of punjab, pakistan. J Agric Res. 2020; 58(1):49–57.

34. Belayneh M, Loha E, Lindtjørn B. Seasonal Variation of Household Food Insecurity and Household Dietary Diversity on Wasting and Stunting among Young Children in A Drought Prone Area in South Ethiopia: A Cohort Study. Ecology of food and nutrition. 2021; 60(1):44–69. https://doi.org/10.1080/03670244.2020.1789865 PMID: 32672490

35. Bosha T, Lambert C, Riedel S, Melesse A, Biesalski HK. Dietary Diversity and Anthropometric Status of Mother-Child Pairs from Enset (False Banana) Staple Areas: A Panel Evidence from Southern Ethiopia.

International journal of environmental research and public health. 2019; 16(12). https://doi.org/10.3390/ijerph16122170 PMID: 31248176; PubMed Central PMCID: PMC6617300.

36. Ravaoarisoa, et al. Food consumption and undernutrition variations among mothers during the post harvest and lean seasons in Amoro'i Mania Region, Madagascar. BMC public health. 2019; 19(1005):3–9. https://doi.org/10.1186/s12889-019-7333-9 PMID: 31349840

37. Fox Elizabeth L., Claire Davis, Downs Shauna M., Schultink Werner, Fanzo Jessica. Who is the Woman in Women's Nutrition? A Narrative Review of Evidence and Actions to Support Women's Nutrition throughout Life. CURRENT DEVELOPMENTS IN NUTRITION. 2019; 3(1):nzy076. https://doi.org/10.1093/cdn/nzy076.

38. Fite MB, Tura AK, Yadeta TA, Oljira L, Roba KT. Factors associated with food consumption score among pregnant women in Eastern Ethiopia: a community-based study. Journal of Health, Population and Nutrition. 2022; 41(1):6. https://doi.org/10.1186/s41043-022-00286-x PMID: 35232495

39. Saaka M, Mutaru S, Osman SM. Determinants of dietary diversity and its relationship with the nutritional status of pregnant women. J Nutr Sci. 2021;2(10). https://doi.org/10.1017/jns.2021.6 PMID: 33889397

40. Bryson JM, Patterson K, Berrang-Ford L, Lwasa S, Namanya DB, Twesigomwe S, et al. Seasonality, climate change, and food security during pregnancy among indigenous and non-indigenous women in rural Uganda: Implications for maternal-infant health. PloS one. 2021; 16(3):e0247198. https://doi.org/10.1371/journal.pone.0247198 PMID: 33760848

41. Palacios-Lopez A, Christiaensen L, Kilic T. How much of the labor in African agriculture is provided by women? Food Policy. 2017; 67:52–63. https://doi.org/10.1016/j.foodpol.2016.09.017 PMID: 28413246

42. Bureau SRH. Sidama Regional Health Bureau 2015 EFY Health facility & population Profile. 2022.

43. Matewos T. Climate Change-Induced Impacts on Smallholder Farmers in Selected Districts of Sidama, Southern Ethiopia. Climate. 2019; 7(5):70. https://doi.org/10.3390/cli7050070

44. Food and agriculture organization of the united state (FAO). ETHIOPIA: Crop and Livestock Situation for Drought Affected Areas—September 2022.

45. Brandt S, Spring A, Hiebsch C, McCabe J, Tabogie E, Diro M, et al. The Tree Against Hunger: Enset-Based Agricultural Systems in Ethiopia 1997.

46. Taffesse Samson, Grazia Maria, Girma Woldemariam. Maternal energy and macronutrient insecurity in an ensete-corn staple village of Southern Ethiopia. Ethiopia Journal of Health Development. 1999; 13(3):285–90.

47. Mekides Wolde, Yifru Berhan, and Alemzewed Chala. Determinants of underweight, stunting and wasting among schoolchildren. BMC public health. 2015; 15(8).

48. Galato Zerhun Ganewo. Impact of productive safety net program on household asset building, food security and annual income in Sidama Zone, Southern Ethiopia. International Journal of Current research. 2020; 12(02).

49. Asefach Hailu, Nigatu Regassa. Correlates of Household Food Security in Densely Populated Areas of Southern Ethiopia: Does the Household Structure Matter? Journal of Home and Community Sciences. 2006; 1(2).

50. Beruk Berhanu Desalegn Biruk Jagiso. Low diet diversity and its associated factors among the mothers and their children in agroforestry land use systems of Sidama, Ethiopia: A community-based cross-sectional study. Cogent Food & Agriculture. 2020; 6(1).

51. Hameso Seyoum Yunkura. Perceptions, vulnerability and adaptation to climate change in Ethiopia: the case of smallholder farmers in Sidama: University of East London; 2015.

52. Food and Nutrition Technical Assistance III Project (FANTA). Nutrition Assessment, Counseling, and Support (NACS): A User's Guide—Module 2: Nutrition Assessment and Classification. Version 2. Washington DC: FHI 360/FANTA, 2016.

53. Swindale A., Bilinsky P. Household Dietary Diversity Score (HDDS) for measurement of household food access: Indicator guide. Washington, D.C: FHI 360/FANTA, 2006.

54. Jennifer Coates, Anne Swindale, Paula Bilinsky. Household Food Insecurity Access Scale (HFIAS) for Measurement of Household Food Access: Indicator Guide. Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development, August 2007.

55. Kabalo BY, Gebreyesus SH, Loha E, Lindtjørn B. Performance of an adapted household food insecurity access scale in measuring seasonality in household food insecurity in rural Ethiopia: a cohort analysis. BMC Nutr. 2019; 5(54):019–0323.

56. Gebreyesus SH, Lunde T, Mariam DH, Woldehanna T, Lindtjørn B. Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia? BMC Nutrition. 2015; 1(1):2. https://doi.org/10.1186/2055-0928-1-2

57. Lisa Hjelm, Astrid Mathiassen, Darryl Miller, Amit W. VAM guidance paper: Creation of a wealth index. In: World food programme, editor. 2017.

58. StataCorp. Stata: Release 13 Statistical Software. College Station TX: StataCorp LP, 2013.

59. Waswa LM, Jordan I, Krawinkel MB, Keding GB. Seasonal Variations in Dietary Diversity and Nutrient Intakes of Women and Their Children (6–23 Months) in Western Kenya. Frontiers in Nutrition. 2021; 8 (80). https://doi.org/10.3389/fnut.2021.636872 PMID: 33763444

60. Kabeta T, Holst R, Wondafrash B, Frigessi A, Gebremariam M. Determinants of Household Dietary Diversity in Rural Ethiopia: A Household Panel Study 2022.

61. Irenso AA, Atomsa GE. Implications of Ethiopian Productive Safety Net Programme on household dietary diversity and women's body mass index: a cross-sectional study. Food Nutr Res. 2018; 62(1). https://doi.org/10.29219/fnr.v62.1574 PMID: 30574045

62. Kebede TB, Mengesha S, Lindtjorn B, Engebretsen IMS. Anaemia, anthropometric undernutrition and associated factors among mothers with children younger than 2 years of age in the rural Dale district, southern Ethiopia: A community-based study. Matern Child Nutr. 2022; 18(4):25.

63. Boke MM, Yesuf A, Gutema BT. Prevalence of Undernutrition and Associated Factors among Lactating Mothers of Angecha District, Kembata Tembaro Zone, Southern Ethiopia. Journal of nutrition and metabolism. 2021; 2021:6691982. https://doi.org/10.1155/2021/6691982 PMID: 33996153

64. Motbainor A, Worku A, Kumie A. Household food insecurity is associated with both body mass index and middle upper-arm circumference of mothers in northwest Ethiopia: a comparative study. Int J Womens Health. 2017; 9:379–89. https://doi.org/10.2147/IJWH.S130870 PMID: 28603432

65. Korir Lilian, Rizov Marian, Eric Ruto Diet diversity, malnutrition and health: Evidence from Kenya. Journal of Agricultural Economics. 2022.

66. Hadley Craig L. Crooks Deborah Coping and the Biosocial Consequences of Food Insecurity in the 21st Century. YEARBOOK OF PHYSICAL ANTHROPOLOGY 55:72–94 (2012. 2012; 55:72–9.

67. Gelebo DG, Gebremichael MA, Asale GA, Berbada DA. Prevalence of undernutrition and its associated factors among pregnant women in Konso district, southern Ethiopia: a community-based cross-sectional study. BMC Nutrition. 2021; 7(1):32. https://doi.org/10.1186/s40795-021-00437-z PMID: 34247657

68. Locks LM, Patel A, Katz E, Simmons E, Hibberd P. Seasonal trends and maternal characteristics as predictors of maternal undernutrition and low birthweight in Eastern Maharashtra, India. Matern Child Nutr. 2021; 17(2):1. https://doi.org/10.1111/mcn.13087 PMID: 33006259

69. Khudri MM, Rhee KK, Hasan MS, Ahsan KZ. Predicting nutritional status for women of childbearing age from their economic, health, and demographic features: A supervised machine learning approach. PloS one. 2023; 18(5):e0277738. https://doi.org/10.1371/journal.pone.0277738 PMID: 37172042

70. Ikoona EN, Toure MA, Njenga A, Namulemo L, Kaluya R, Kamara K, et al. Prevalence and factors associated with underweight among 15–49-year-old women in Sierra Leone: a secondary data analysis of Sierra Leone demographic health survey of 2019. BMC Women's Health. 2023; 23(1):192. https://doi.org/10.1186/s12905-023-02358-4 PMID: 37085835

71. Zemene MA, Mengistu NW, Nigatu SG. Trends and factors associated with thinness among late adolescent girls in Ethiopia: Multivariate decomposition and multilevel analysis. Frontiers in Nutrition. 2022;9. https://doi.org/10.3389/fnut.2022.933895 PMID: 36061901

72. Desalegn TA, Gebremedhin S, Stoecker BJ. Successes and challenges of the Home-grown School Feeding Program in Sidama Region, Southern Ethiopia: a qualitative study. J Nutr Sci. 2022; 30(11). https://doi.org/10.1017/jns.2022.77 PMID: 36304822

73. Anna Ferro-Luzzi, et al. Seasonal Undernutrition in Rural Ethiopia Magnitude, Correlates, and Functional Significance. International Food Policy Research Institute Washington, D.C., and Istituto Nazionale della Nutrizione, Rome in collaboration with, Ethiopian Health and Nutrition Research Institute, Addis Ababa, 2001.

74. Mengistu Abenet, Mesfin Aklilu. Productive Safety Net Programme, Public Works operation And Maintenance Guideline. A practical guideline manual for development agents in Ethiopia. In: Natural Resource Sector of the Ministry of Agriculture, editor. Ethiopia 2014.

75. Stephen Devereux, and Jonas Nzabamwita. Social Protection, Food Security and Nutrition in Six African Countries. Institute of Development Studies, 2018 Contract No.: 518.

76. Hailu AG, Amare ZY. Impact of productive safety net program on food security of beneficiary households in western Ethiopia: A matching estimator approach. PloS one. 2022; 17(1):e0260817. https://doi.org/10.1371/journal.pone.0260817 PMID: 35061681

77. Kabalo BY, Lindtjørn B. Seasonality and predictors of childhood stunting and wasting in drought-prone areas in Ethiopia: a cohort study. BMJ open. 2022; 12(11):e060692. https://doi.org/10.1136/bmjopen-2021-060692 PMID: 36356996