


# Increased food crop diversification and gathering of wild plants associated with women's dietary diversity in Chad

Marta Mascareñas-García<sup>1,2,3</sup> | Estefania Custodio<sup>3,4</sup>  | Mahamat Garba Issa<sup>5</sup> | M. Bechir<sup>5</sup> | Francois Kayitakire<sup>6</sup>

<sup>1</sup>Department of Preventive Medicine and Public Health, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

<sup>2</sup>Department of Preventive Medicine and Public Health, University Hospital Complex of Santiago de Compostela, Santiago de Compostela, Spain

<sup>3</sup>Centro Nacional de Medicina Tropical, Instituto de Salud Carlos III, Madrid, Spain

<sup>4</sup>Centro de Investigación Biomédica en Red de Enfermedades Infecciosas (CIBERINF), Madrid, Spain

<sup>5</sup>Direction de la Nutrition et de la Technologie Alimentaire, Ministère de la Santé Publique, N'Djamena, Chad

<sup>6</sup>European Commission Joint Research Centre, Ispra, Italy

## Correspondence

Francois Kayitakire, European Commission-Joint Research Centre, Via Enrico Fermi 2749, Ispra 21027, Varese, Italy.  
Email: [francois.kayitakire@ec.europa.eu](mailto:francois.kayitakire@ec.europa.eu)

## Funding information

European Commission Joint Research Centre, Grant/Award Number: 154591.X6

## Abstract

Women of reproductive age are particularly vulnerable to low-quality diets due to their higher micronutrient needs. The minimum dietary diversity for women (MDDW) is a proxy for micronutrient adequacy in this group of women. Its relationship with other aspects that lead to malnutrition is not fully elucidated and depends on the context. In this study, we assessed the prevalence of MDDW among women of a rural area in Chad and its association with socioeconomical, agricultural, dietary and food security data. A cross-sectional study was conducted. Following a multistage cluster sampling, 984 women of reproductive age were randomly selected and interviewed in March 2019. We obtained food consumption data through unquantified 24 h recalls and computed MDDW as consuming at least five out of 10 predefined food groups. We constructed a Food Production Diversity Score (FPDS) with crop and livestock information. We obtained multivariable logistic regression models including different covariates. MDDW was achieved by only 33% of women in the sample. In our final model, we identified a significant association of MDDW with the FPDS and gathering of wild plants. Women in households with the highest FPDS had 70% more chances of achieving MDDW than those with the lowest FPDS. Gathering wild plants doubled these chances. Areas of cultivated land, Water, Sanitation and Hygiene resources, and a high level of food security, measured with the Household Food Insecurity Access Scale, were also significantly related to the achievement of MDDW. This illustrates the importance of nutrition-sensitive policies, also considering biodiversity and food production diversification.

## KEYWORDS

Chad, dietary diversity, food production, micronutrient, women of reproductive age

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial](https://creativecommons.org/licenses/by-nc/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

© 2024 European Commission. *Maternal & Child Nutrition* published by John Wiley & Sons Ltd.

## 1 | INTRODUCTION

Dietary diversity is one of the essential components of a quality diet and is key to reaching micronutrient dietary adequacy. For women of reproductive age, the requirements of certain micronutrients are higher, especially when pregnant or lactating (Bartley et al., 2005). Micronutrient deficiencies have a direct effect on women's health and also on their offspring—especially during the first 1000 days—resulting in negative outcomes such as stillbirths or foetal growth retardation (Darnton-Hill & Mkpuru, 2015).

Chad is off course to meet all global nutrition targets for maternal, infant and young child nutrition (World Health Organization, 2014). Around 45% of women aged 15–49 years are affected by anaemia and 31% of children under 5 years suffer chronic malnutrition, which is higher than the average for the Africa region (30.7%) (Development Initiatives Poverty Research Ltd, 2022). Furthermore, 1.9 million children under 5 years and 346,580 pregnant and lactating women are estimated to be wasted (Integrated Food Security Phase Classification, 2021).

The Minimum Dietary Diversity (MDDW) indicator was developed and validated to serve as a proxy indicator of the level of micronutrient adequacy in women of reproductive age (15–49 years) (FAO, 2016) and is increasingly being used as an indicator of nutrition-sensitive programmes and policies related to sectors like food security, agriculture or education, among others.

To maximize the nutritional impact of the actions from these sectors it is important to understand how the MDDW indicator relates to the food security and agriculture dimensions, among others. Studies from other African countries have shown direct association of the MDDW with the household's (HH's) food security (Aubra et al., 2019; Custodio et al., 2015; Huang et al., 2018; Roba et al., 2019), as well as with variables reflecting different agricultural activities within the HH like the variety of crops cultivated or the livestock rearing (Aubra et al., 2019; Anyanwu, Ghosh, Kershaw, Abuye, et al., 2022; Gitagia et al., 2019; Huang et al., 2018; Ludwig, 2018; Melby et al., 2020; Singh et al., 2020).

Chad is one of the priority countries for the Nutrition Action Plan of the European Union due to its high rate of under nutrition and strong potential to reduce it (EuropeAid, 2015). The country shows high levels of food insecurity and it hosts the largest number of displaced persons in West Africa and the Sahel. It is highly dependent on agriculture and livestock and is considered one of the five countries most vulnerable to climate change (FSIN and Global Network Against Food Crises, 2023). The European Union (EU) is implementing a multisectoral plan on food security and nutrition in Chad<sup>1</sup> to tackle all these issues, which includes nutrition-sensitive interventions (EuropeAid, 2021). To evaluate the impact of the project the EU requested to their internal science service (the European Commission Joint Research Centre) the implementation of a project to assess the operationalization of collecting

### Key messages

- Only one in three women in a rural area of the Guerá region in Chad reach the minimum dietary diversity measured by the minimum dietary diversity for women (MDDW) indicator.
- Food insecurity is highly prevalent among households (HHs) of these rural areas of Chad, with more than 90% of the HHs being moderately or severely food insecure.
- Diverse food production and gathering of wild foods in HHs has a positive impact on MDDW.
- Water, Sanitation and Hygiene resources, areas of cultivated land and greater HH food security also showed this positive association. Altogether, this indicates the importance of nutrition-sensitive policies that address malnutrition through a holistic approach.

nutrition-sensitive indicators like the MDDW and to provide scientific evidence of the baseline situation in one of the areas of interest of the project, the Guerá region. The project was designed and implemented in collaboration with the National Direction of Nutrition and Food Technology from the Ministry of Public Health in Chad.

The aim of this study is to provide scientific evidence on the determinants of women's dietary diversity in the Guerá region in Chad.

## 2 | METHODS

### 2.1 | Study area and population

The study area was located in the Guerá region, one of the 23 regions of Tchad (Administrative level 1) and more specifically in the department of Abtouyour, one of the four departments (Administrative level 2) of the Guerá region. We selected this department, because it was one of the target areas of the Food and Nutrition Security EU programme. The harvesting season in Chad is from September to December and the lean season from June to August (Food and Agriculture Organization of the United Nations, 2023).

The department of Abtouyour has a population estimate of 177,850 inhabitants and 217 villages, with an average of cultivated area per HH of 2 hectares (ht). Sorghum is the most cultivated cereal in both the region and the department, followed by berbére and the average sack production of cereals is between 10 and 15 sacks per year (100 kg per sack) for the whole department. HHs have an average number of one to five heads of cattle and six to 10 heads of sheep and/or goats, and traditional wells are the most common infrastructure for water use in the rural areas (OXFAM, 2016).

<sup>1</sup><https://programmesan.org/>.

## 2.2 | Sampling and study design

We designed the sampling procedure using multistage cluster sampling and calculated the sample size using the following parameters: 30% expected MDDW as per literature review in similar populations (Aubra et al., 2019; Custodio et al., 2015), a design effect of 2.5, due to cluster sampling and a precision of 5%. We added 20% to account for HHs with no women of reproductive age and potential participation refusals, and the resulting sample size was 967 HHs that we rounded up to 1000 HHs.

The primary sampling units (PSUs) were the villages in the department of Abtouyour. We established a fixed cluster or PSU size of 25 HHs and randomly selected a total of 40 villages from the 212 villages in Abtouyour (INSEED, 2009). The secondary sampling units were the HHs within the selected villages, which were numbered to create the sampling frame. Subsequently, we employed systematic random sampling to select 25 HHs from each village. In the final step, we listed all women of reproductive age present in the selected HHs at the time of the survey and only one woman was randomly chosen for interview.

## 2.3 | Data collection

The data collection was carried out by an expert team of enumerators from the National Direction of Food Technology and Nutrition. They received tailored training for data collection of the survey during 1 week.

The data were collected by using person-to-person interview with self-elaborated questionnaires adapted to digital devices or tablets using the ODK mobile data collection platform.<sup>2</sup> Data were collected in March 2019.

We collected information on HH's socio-demographic and economic characteristics, on food security and agricultural practices, as well as on food groups' (FGs') consumption by women of reproductive age.

The sections of the questionnaire regarding HH demographic composition, assets, food security and agricultural characteristics were directed to the head of the HH, while the individual dietary questions were addressed to the selected woman of reproductive age. Data collection for the calculation of the MDDW was conducted through qualitative 24 h open dietary recall. Women were asked to detail all foods and beverages consumed during the preceding day and night. Enumerators recorded this information on paper and then classified the food into an extended list of 22 predefined FGs in the tablet at the end of the interview, following FAO's guidelines on MDDW data collection (FAO, 2021).

To measure HH food security we used the Household Food Insecurity Access Scale (HFIAS), utilizing a standardized questionnaire with a 30-day recall period (Coates et al., 2007).

## 2.4 | Variables construction

To construct the MDDW, we grouped the 22 FGs into 10 predefined groups (1: Grains, white roots and tubers, and plantains; 2: Pulses; 3: Nuts & seeds; 4: Dairy; 5: Meat, poultry and fish; 6: Eggs; 7: Vitamin A dark green leafy vegetables; 8: Other vitamin A-rich fruits and vegetables; 9: Other vegetables; 10: Other fruits). Each FG was as assigned a value of 1 if consumed, regardless of consumption frequency, but adhering to the minimum 15 g rule outlined in the FAO guidelines (FAO, 2021). We summed them up to obtain the Women's Dietary Diversity Score (WDDS-10), ranging from zero to 10. Subsequently, we constructed the MDDW dichotomous variable. This variable is assigned a value of 1 if the number of FGs consumed or the WDDS-10 is five or above and a value of 0 if the consumption of FGs is below five (FAO, 2021).

The food security proxy was based on responses to the HFIAS questionnaire. Respondents provided frequency-based responses categorized as: 1, *rarely*; 2, *sometimes*; and 3, *often*. Responses of 'no' were computed as zero. The final average points of the score ranged between 0 and 27. Subsequently, this score was categorized into levels of food security, including food secure, mildly food insecure, moderately food insecure and severely food insecure following HFIAS construction guidelines (Coates et al., 2007).

To assess the diversification in the HH food production, we developed a Food Production Diversity Score (FPDS) following the procedures outlined by Aubra et al. (2019). Respondents reported food production in the HH over the past 12 months. Crops were categorized into five groups: Grains & Tubers; Beans, Peas & Pulses; Nuts & Seeds; Fruits and Vegetables. Livestock were classified into three groups: Poultry, Cattle and Goats & Sheeps. Each crop and livestock group was assigned one point and the sum of all points resulted in the HH FPDS. This score ranged between 0 and 8 points.

The gathering of wild foods also referred to the past 12 months and was reported by the respondent of the survey. These foods were then classified into Plants, Fruits, Nuts & Seeds and Animals (including hunting, fishing and insects gathering).

We developed a proxy for the Water, Sanitation and Hygiene (WASH) dimension using three variables as follows: (1) the presence of a potabilization system; (2) existence of any type of toilet facility; and (3) a reported habit of handwashing with soap. Each positive response earned one point to the corresponding HH, resulting in a score ranging from 0 to 3. Categories included 0, *No WASH resources*; 1, *Low WASH resources*; 2–3, *High WASH resources*.

The area of cultivated land, measured in hectares (ht), was categorized into four groups: 0–0.5, 0.6–1, 1.1–2, 2.1–10 ht.

## 2.5 | Statistical analysis

Statistical analysis was performed with IBM SPSS Statistics version 20.

First, we performed descriptive statistics calculating the mean and SD of continuous variables like the age of respondents and of

<sup>2</sup><https://getodk.org/>.

other members of the family and the HFIAS continuous index, as well as the median and interquartile range (IQR) of the variable number of people in the HH. For categorical variables, we computed for these two groups of women the frequency and relative proportion of each category like level of education attained, food security classification according to HFIAS and so on. We performed these computations disaggregated by women achieving MDDW and women not achieving MDDW.

In a second step, we performed logistic bivariable analysis using MDDW as the dependent variable and the sociodemographic, food security and WASH variables as the independent ones.

Finally, we constructed a multivariable logistic regression model using a manual forward stepwise procedure, entering all the covariates that were associated with MDDW at the  $p < 0.05$  level in the previous bivariate analysis. All the variables that were associated with MDDW at the  $p < 0.05$  level remained in the final model.

## 2.6 | Ethical considerations

During the field work participants gave written informed consent before participating in the survey.

We submitted the study design and the survey instrument for ethics review in accordance with Helsinki declaration and the Ethics Committee of the Chad Public Health Ministry approved it in April 2018 (N°0737/PR/PM/MSP/DGAS/DNTA/2018).

## 3 | RESULTS

A total of 984 women were interviewed. The median HH size was six (IQR: 4–8) and the mean number of children under 5 years old in the households was 4.05 (SD: 3.65). Male HH heads accounted for 76.5% of the HH. The mean age of HH head was 40.76 years (SD: 12.15), while the mean age of the respondent women was 27.62 (SD: 8.32). Approximately half of the HH heads had no formal education (48.5%). Among female HH heads, 63.6% had no education, compared to 43.8% among male HH heads. Overall, 52.8% of the HHs were classified as severely food insecure according to the HFIAS, increasing to 59.8% among HH of women who did not achieve the MDDW (Table 1). Most respondents (82.2%) reported August as the worst month in relation to food availability and access, while 46.4% and 33.6% reported October and November, respectively, as the best months.

Only 32.8% of women achieved MDDW (consuming five groups of more out of the 10 predefined FGs), with mean of WDDS-10 of 4.01 FGs (SD: 1.43). The most consumed FG was 'Starchy foods', followed by 'Vitamin A-rich dark green leafy vegetables' and 'Other vegetables' groups. Women who achieved MDDW and those who did not had similar consumption of 'Starchy foods' and 'Eggs'. The rest of the FGs were all the more consumed by women who achieved MDDW and the greatest differences were observed in the 'Vitamin

A-rich vegetables and fruits', 'Nuts & Seeds', 'Flesh Food' and 'Other Fruits' groups (see Figure 1).

In Figure 2, we depict the composition of FGs in the diet, illustrating how it varies depending on the number of FGs consumed, ranging from 1 to 9. All women (100%) who consumed only one FG exclusively consumed starchy foods. Conversely, all the women (100%) that consumed nine FG the day before consumed the following eight FGs: 'Starchy', 'Nuts & Seeds', 'Dairy', 'Flesh foods', 'Vitamin A-rich leafy vegetables', 'Vit A-rich vegetable and fruits', 'Other vegetables' and 'Other fruits'. However, the ninth group was 'Eggs' for 33% of the women and 'Beans & Peas' for 67% of them.

The FPDS ranges from 0 to 8 and its mean HH value in our sample was 2.93 (SD: 1.44), increasing to 3.16 (SD: 1.58) in HHs where women achieved MDDW and decreasing to 2.81 (SD: 1.36) in HHs where women did not achieve MDDW. The median cultivated land area was 1 ht (IQR: 1–2) with the most frequently cultivated crops belonging to the 'Grains and Tubers' FG (89.6%) followed by 'Nuts & Seeds' (81.7%). Associations were found between growing 'Nuts & Seeds' crops and their consumption ( $p = 0.001$ ), as well as between having fruit trees and/or vegetables crops and the consumption of 'Other vitamin A-rich vegetables and fruits' ( $p < 0.001$  for both).

Relative to animal source foods, less than half of the HH owned livestock (43.9%,  $n = 432$ ), primarily 'Poultry' (27.4%,  $n = 270$ ) and goats/sheep 'Goats & Sheeps' (25.5%,  $n = 251$ ) (Table 1). Although the presence of livestock was positively associated with the consumption of flesh foods, this association was not significant.

Wild foods were collected by 77% ( $n = 758$ ) of HHs, predominantly wild fruits (75.2%,  $n = 740$ ) and wild plants (38.5%,  $n = 379$ ). Only a minority reported hunting, fishing or insect gathering (10%,  $n = 98$ ), or gathering nuts/seeds (5%,  $n = 49$ ) (Table 1). Consumption of 'Other fruits' was associated with gathering wild fruits ( $p < 0.001$ ) and HHs gathering wild plants reported significantly higher consumption of the 'Vitamin A-rich leafy vegetables', the 'Vit A-rich vegetables' and the 'Other vegetables' groups ( $p < 0.001$ ,  $p = 0.017$  and  $p = 0.002$ , respectively). No association was found between hunting, fishing or insects gathering and the consumption of 'Flesh foods' at HH level.

The WASH resources were scarce, with 64% of HHs ( $n = 627$ ) lacking any considered resource. Among HHs with at least one resource, only 3.6% ( $n = 35$ ) had all three (potabilization system, toilet facility and handwashing with soap), 6.7% had two of them and 26% only one (data not shown in tables). Just 6.5% of the sample treated water in some way, toilets were available in 14.5% of the HH and in only 29.1% of the HHs they washed their hands with soap (Table 1).

Several variables were significantly associated with MDDW in bivariate analyses: inversely with the HFIAS and directly with educational level of the head of the HH, HH size, FPDS, cultivated land area, number of WASH resources and wild food gathering, overall, and more specifically the gathering of wild fruits and wild plants (Supporting Information S1: Annex Table A1).

The head of the HH being male was positively associated with MDDW although the association was not significant ( $p = 0.059$ ). No association was found between MDDW and the age of the head of

**TABLE 1** Individual and HH characteristics of the sample, stratified by the achievement of MDDW by the respondent women.

	All (N = 984)	Women achieving MDDW (N = 323)	Women not achieving MDDW (N = 661)
MDDW respondent age, mean (SD)	27.62 (8.32)	27.01 (8.44)	27.92 (8.26)
HH head sex (man), n (%)	753 (76.5)	259 (80.2)	494 (74.7)
HH head age, mean (SD)	40.76 (12.15)	40.80 (11.95)	40.74 (12.25)
Number of people in the HH, median (IQR)	6 (4-8)	6 (5-8)	6 (4-7.5)
Children < 5 years, mean (SD)	4.05 (3.65)	4 (3.64)	4.08 (3.66)
HH head education, n (%)			
Not educated	477 (48.5)	135 (41.8)	342 (51.7)
Primary education	355 (36.1)	124 (38.4)	231 (34.9)
Secondary education or higher	152 (15.4)	64 (19.8)	88 (13.3)
HFIAS, mean (SD)	16.58 (5.40)	14.76 (5.26)	17.47 (5.24)
HH food insecurity, <sup>a</sup> n (%)			
Severely food insecure	520 (52.8)	125 (38.7)	395 (59.8)
Moderately food insecure	388 (39.4)	162 (50.2)	226 (34.2)
Mildly food insecure	67 (6.8)	29 (9)	38 (5.7)
Food secure	9 (0.9)	7 (2.2)	2 (0.3)
FPDS, n (%)			
0-2	422 (42.9)	121 (37.5)	301 (45.5)
3-4	421 (42.8)	138 (42.7)	283 (42.8)
5-8	141 (14.3)	64 (19.8)	77 (11.6)
Crops, n (%)			
Grains & tubers	882 (89.6)	285 (88.8)	597 (90.3)
Beans, peas and pulses	164 (16.7)	62 (19.2)	102 (15.4)
Nuts & seeds	804 (81.7)	271 (83.9)	533 (80.6)
Fruits	111 (11.3)	51 (15.8)	60 (9.1)
Vegetables	292 (29.7)	120 (37.2)	172 (26)
Livestock, n (%)			
Poultry	270 (27.4)	106 (32.8)	164 (24.8)
Cattle	108 (11)	33 (10.2)	75 (11.3)
Goats and sheeps	251 (25.5)	94 (29.1)	157 (23.8)
Area of cultivated land, n (%)			
0-0.5 ht	232 (23.8)	47 (14.7)	185 (28.3)
0.6-1 ht	359 (36.9)	120 (37.4)	239 (36.6)
1.1-2 ht	259 (26.6)	103 (32.1)	156 (23.9)
2.1-10 ht	124 (12.7)	51 (15.9)	73 (11.2)
WASH resources, n (%)			
Water potabilization	64 (6.5)	35 (10.8)	29 (4.4)
Handwashing with soap	286 (29.1)	115 (35.6)	171 (25.9)
Toilet	143 (14.5)	74 (22.9)	69 (10.4)

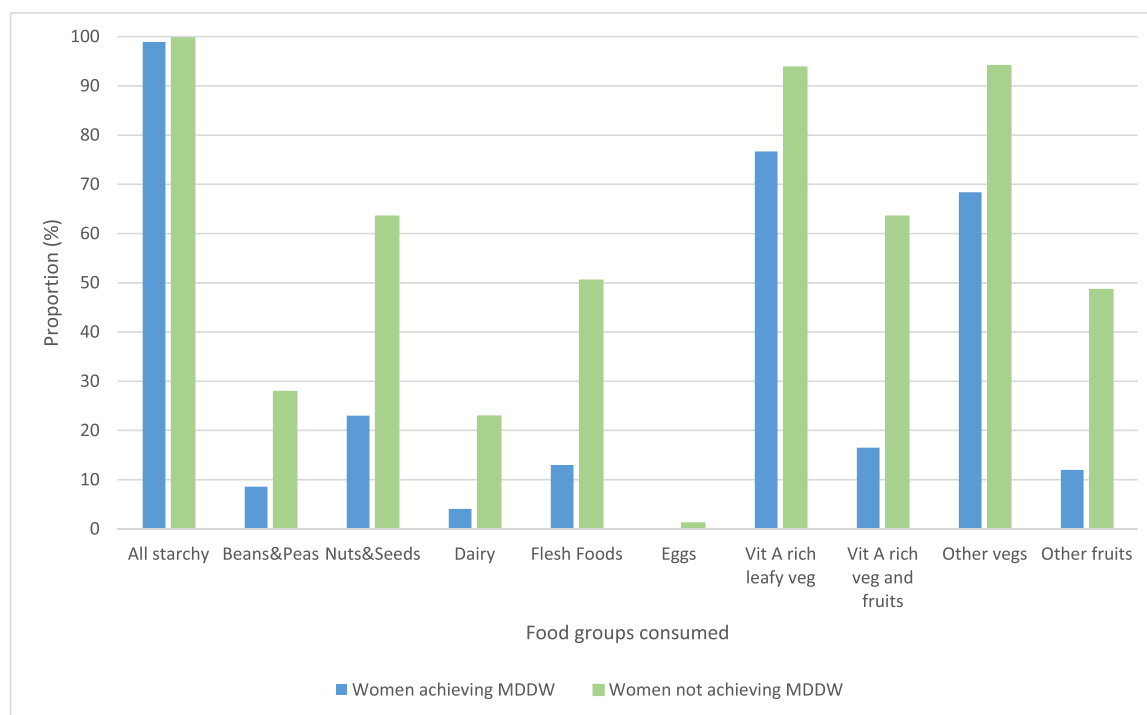
(Continues)

TABLE 1 (Continued)

	All (N = 984)	Women achieving MDDW (N = 323)	Women not achieving MDDW (N = 661)
Wild foods gathering, n (%)			
Any	758 (77)	261 (80.8)	497 (75.2)
Plants	379 (38.5)	160 (49.5)	219 (33.1)
Fruits	740 (75.2)	256 (79.3)	484 (73.2)
Nuts & seeds	49 (5)	18 (5.6)	31 (4.7)
Animals (fishing, insects or haunting)	98 (10)	29 (9)	69 (10.4)

Abbreviations: FPDS, Food Production Diversity Score; HFIAS, Household Food Insecurity Access Scale; HH, household; IQR, interquartile range; MDDW, Minimum Dietary Diversity; WASH, Water, Sanitation and Hygiene.

<sup>a</sup>Based in the HFIAS index, see the Section 2.



**FIGURE 1** Food groups' consumption reported by women achieving Minimum Dietary Diversity (MDDW) and women not achieving MDDW.

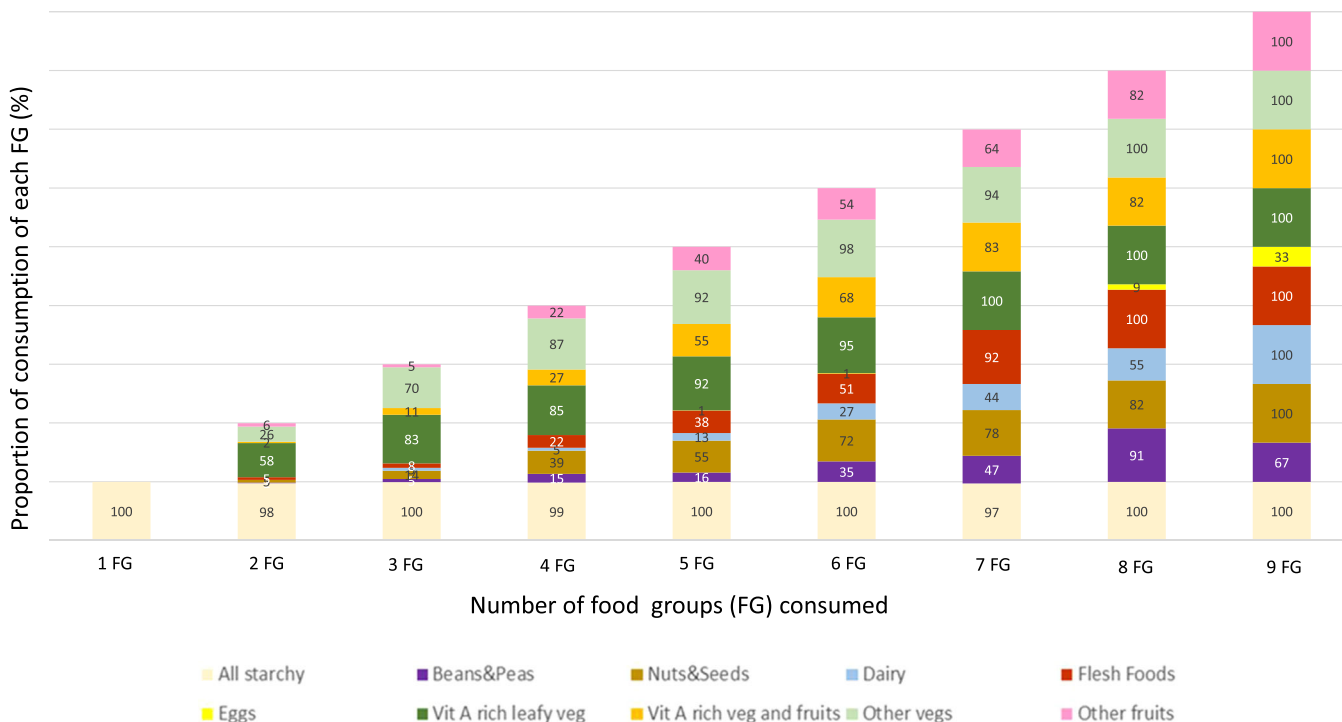
the HH, or the number of children under 5 years of age living in the HH (Supporting Information S1: Annex Table A1).

When we built the multivariable regression model, the sample size was reduced to 974 women due to missing values in the independent variables. In addition, some variables lost significant association with MDDW (education of head of the HH, HH size and wild fruit gathering). In Table 2, we show the results of the adjusted model. The likelihood of reaching MDDW was significantly increased when the FPDS was 5 or more (odds ratio [OR]: 1.71 [interval confidence (IC) 95%: 1.10–2.66],  $p=0.017$ ) as compared to a FPDS below three. The HFIAS and the MDDW were inversely related. With each increasing point of the HH food insecurity measured by the HFIAS, the likelihood of achieving MDDW was reduced by 9% (OR: 0.91 [IC 95%: 0.89–0.94],  $p < 0.001$ ).

This means that women living in HHs with food insecurity were less likely to achieve MDDW. The mean value of HFIAS for the HH with women reaching MDDW was 14.76.

Moreover, the chances for women to achieve MDDW increased with the number of hectares of cultivated land. All the categories in this variable remained significant in our model ( $p \leq 0.001$ ). The likelihood of reaching MDDW increased by more than two times with the HH owning 0.6–1 ht (OR: 2.13 [IC 95%: 1.38–3.28]), or 1.1–2 ht (OR: 2.78 [IC 95%: 1.76–4.38]) as compared to owning <0.5 ht. Moreover, women living in HHs with 2.1–10 ht had almost three times more chances of reaching MDDW (OR: 2.94 [IC 95%: 1.72–5.06]).

WASH resources also had a significant impact on MDDW. Even women living in HHs with what we considered low WASH resources



**FIGURE 2** Proportion of consumption of each food group (FG) according to the total number of FGs consumed by the women the day before.

**TABLE 2** Factors associated with MDDW in the Guera region, Chad.

Variable	OR	IC 95%	p
HFIAS	0.91	(0.89–0.94)	<0.001
FPDS low (0–2)	Ref.	Ref.	Ref.
FPDS medium (3–4)	1.03	(0.74–1.43)	0.865
FPDS high (5–8)	1.71	(1.10–2.66)	0.017
0–0.5 ht of area cultivated land	Ref.	Ref.	Ref.
0.6–1 ht of area cultivated land	2.13	(1.38–3.28)	0.001
1.1–2 ht of area cultivated land	2.78	(1.76–4.38)	<0.001
2.1–10 ht of area cultivated land	2.94	(1.72–5.06)	<0.001
No WASH resources: 0	Ref.	Ref.	Ref.
Low WASH resources: 1	1.44	(1.03–2.00)	0.035
High WASH resources: 2–3	4.77	(2.91–7.80)	<0.001
Wild plants gathering	1.98	(1.47–2.68)	<0.001

Note: Results from the multivariable logistic model with MDDW as independent variable.

Abbreviations: FPDS, Food Production Diversity Score; HFIAS, Household Food Insecurity Access Scale; IC, interval confidence; MDDW, Minimum Dietary Diversity; OR, odds ratio; WASH, Water, Sanitation and Hygiene.

had 1.44 more chances of achieving MDDW than those living with no WASH resource whatsoever. In HH with high WASH resources, women had their chances of achieving MDDW multiplied almost by 5 (OR: 4.77 [IC 95%: (2.91–7.80);  $p < 0.001$ ] (Table 2).

Finally, the likelihood to reach MDDW for women living in HH that gathered wild plants almost doubled as compared to HHs that did not (OR: 1.98 [IC 95%: 1.47–2.68],  $p < 0.001$ ) (Table 2).

## 4 | DISCUSSION

In the Department of Abtoyour in the southern Guera region of Chad, only 33% of the women achieved MDDW during the month of March, 3 months after the end of the harvest season and 3 months before the start of the lean season (Food and Agriculture Organization of the United Nations, 2023). To our knowledge, this is the first study published to utilize the MDDW indicator in this country and the observed value appears to be in the middle range when compared to other Sub-Saharan African countries: 27% in Mali (Adubra et al., 2019) 23%–26% in Burkina Faso during the lean season and 30%–49% in the postharvest season (Custodio et al., 2015), 16%–2% in Kenya (Gitagia et al., 2019) and 46% in Tanzania during the lean season (Ochieng et al., 2017). However, these values are lower than those observed in other regions of the world, such as Latin America, where 55% of women consumed at least five of the 10 FGs in a study conducted in the Peruvian Andes (Jones et al., 2018) and 79% in Ecuador (Melby et al., 2020); or North Africa, with a study in Tunisia showing MDDW of 90% over the year (Gaillard et al., 2022).

Furthermore, our results indicate a positive association between MDDW and HH food security, food production diversity, cultivated land area, wild plant gathering and WASH resources. The direct

association between women's dietary diversity and food security aligns with findings from urban Burkina-Faso and rural Ethiopia (Custodio et al., 2020; Roba et al., 2019). In rural Mali, a positive association was found with WDDS-10 and HFIAS, and an even greater association with the Household Hunger Scale (HHS), a score computed from the HFIAS reflecting HH-level hunger experienced (Aubra et al., 2019). In rural Burkina-Faso, HFIAS and HHS were found to be significantly associated with MDDW in one province during the lean season and among HH with a low socioeconomic score (Custodio et al., 2015). Meanwhile, Huang et al. (2018) in Tanzania did not find significance in the relationship between HFIAS and MDDW, although the association was consistently negative.

We assessed food production diversity using the methodology outlined by Aubra et al. (2019) as detailed in Section 2. Although there is no standardized method for measuring farm production diversification, we chose this approach because it utilizes crop groups rather than individual species, making it easier to interpret in relation to MDDW. Ideally, we would have employed the same FGs as those considered for MDDW (Berti, 2015), but this was not feasible due to limitations in the survey data, which precluded classification of crops based on micronutrient content. In the literature, we find other methods to measure crop production diversification, such as the Simpson and Shannon indices mainly used by ecologists to measure diversity (Magurran & McGill, 2011). However, these methods primarily quantify biodiversity rather than diversity based on nutrient content (Ludwig, 2018). Studies employing these methods yield conflicting results: for instance, one study in Kenya found a positive association between MDDW and the Simpson's Index, as well as with a farm production diversity score (Muthini et al., 2020), while another found no association between MDDW and either the production diversity score or the Shannon index (Gitagia et al., 2019). Similarly, a study conducted in Tunisia also found no association (Gaillard et al., 2022), although studies in Ethiopia, Tanzania, India and Ecuador did find such associations (Anyanwu, Ghosh, Kershaw, Abuye, et al., 2022; Huang et al., 2018; Ludwig, 2018; Melby et al., 2020). Lourme-Ruiz et al. (2021) reported mixed results for this association in Burkina Faso and suggested that assessing the relationships between women's dietary diversity and agricultural biodiversity depends on how the latter is measured.

The extent of cultivated land showed a progressively significant association with the attainment of MDDW. This finding aligns with observations made in Ethiopia by Anyanwu, Ghosh, Kershaw, Abuye, et al. (2022).

The gathering of wild plants consistently showed a positive correlation with MDDW. Although our questionnaire only inquired about the gathering, rather than consumption of wild plants, a notable association was evident with both MDDW and the consumption of all vegetables FG. Thus, even if some collected plants are not consumed as food, those that are edible appear to play a crucial role in dietary diversity, potentially linked to increased consumption of dark green leafy vegetables, as described in a study conducted in Benin (Boedecker et al., 2014). Unfortunately, due to the constraints outlined in the FPDS, we were unable to classify

gathered wild plants within the same vegetable FGs as those used in the MDDW survey. Additionally, it's important to note that our survey queried participants about wild plant gathering throughout the year, not specific to any particular season, so there could be variations. The findings from the Benin study support our own, indicating a more adequate micronutrient intake among women who consume wild edible plants, such as leaves (as leafy vegetables), fruits, nuts, or tubers (Boedecker et al., 2014). Similarly, in Benin, researchers demonstrated a positive association between on-farm diversity, encompassing both cultivated crops and gathered wild species, and MDDW (Bellon et al., 2016). The source, type and nutritional contribution of wild foods varies across socio-ecological settings, but there is evidence suggesting their importance for enhancing resilience in communities facing seasonal food insecurity (Powell et al., 2015). Our study underscores the necessity of investing in programmes that consider not only agrobiodiversity but also wild biodiversity in the Guéré region.

In addition, women residing in HHs with improved WASH resources were found to have up to five times higher odds of achieving MDDW, even after adjusting for other covariates. The WASH score variable may serve as an indirect proxy of the HH's wealth. However, findings from another study in Ethiopia suggest that WASH may have an independent effect. Researchers observed a consistent association between WASH and increased odds of achieving MDDW, even after accounting for education and wealth (Anyanwu, Ghosh, Kershaw, Cherinet, et al., 2022). Furthermore, Huang et al. (2018) showed that owning an improved toilet facility and using improved drinking water were associated with higher odds of MDDW although the  $p$  values were only marginally significant ( $p=0.06$  and  $p=0.08$ , respectively) in the multivariable models. Another study by Aubra et al. (2019) found that their wealth index predicted MDDW, incorporating WASH resources into its construction. As we did not construct a wealth index for this study, we can only speculate on the association between the WASH resources and a potential wealth index.

Notably, the education variable, which was significant in the bivariate analysis, lost its significance when WASH resources were included in the model. This underscores the idea that WASH may serve as a proxy for the socioeconomic conditions of HHs.

This study has several limitations worth noting. First, it's important to highlight that data collected on crops, livestock and wild food gathered represents the entire year, whereas the MDDW survey captures dietary information from the previous 24 h. As previously mentioned, it was not feasible to establish the same FGs as those in the MDDW survey for the FPDS, nor was it possible to differentiate which wild plants were actually consumed.

Furthermore, the inherent limitations of a cross-sectional study are evident, providing a static representation, which is also confined to a small area that may not be representative of the whole country.

While more studies across different seasons and settings are necessary, this study illuminates a country where data was previously lacking. Additionally, this information can contribute to the development of nutrition-sensitive policies in low- and middle-income countries, by

highlighting the strong association between food production diversity, wild plant gathering and dietary diversity, which are essential pillars of diet quality.

## AUTHOR CONTRIBUTIONS

Marta Mascareñas-García contributed in data cleaning, statistical analysis, methodology, statistical analysis, interpretation of results and writing of the manuscript draft. Estefania Custodio contributed in study conceptualization, methodology, statistical analysis, interpretation of results, revision and edition of the manuscript and supervision of the manuscript. Mahamat Garba Issa contributed in study conceptualization, methodology, interpretation of results, and revision and edition of the manuscript. M. Bechir contributed in study conceptualization, methodology, interpretation of results, and revision and edition of the manuscript. Francois Kayitakire contributed in study conceptualization, methodology, interpretation of results, and revision and edition of the manuscript.

## ACKNOWLEDGEMENTS

We would like to acknowledge the survey participants and the field enumerators from the Ministry of Public Health in Chad for their collaboration in the data collection process. The funding for this study was provided by the European Commission Joint Research Centre, Specific Contract No. 154591.X6.

## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## ORCID

Estefania Custodio  <http://orcid.org/0000-0002-5514-3151>

## REFERENCES

- Aubra, L., Savy, M., Fortin, S., Kameli, Y., Kodjo, N. E., Fainke, K., Mahamadou, T., Le Port, A., & Martin-Prevel, Y. (2019). The Minimum Dietary Diversity for women of reproductive age (MDD-W) indicator is related to household food insecurity and farm production diversity: Evidence from rural Mali. *Current Developments in Nutrition*, 3(3), nzz002. <https://doi.org/10.1093/cdn/nzz002>
- Anyanwu, O., Ghosh, S., Kershaw, M., Abuye, C., & Kennedy, E. (2022). The role of household assets in improving women's dietary diversity in Ethiopia. *Current Developments in Nutrition*, 6(4), nzab131. <https://doi.org/10.1093/cdn/nzab131>
- Anyanwu, O., Ghosh, S., Kershaw, M., Cherinet, A., & Kennedy, E. (2022). Dietary outcomes, nutritional status, and household water, sanitation, and hygiene (WASH) practices. *Current Developments in Nutrition*, 6(4), nzac020. <https://doi.org/10.1093/cdn/nzac020>
- Bartley, K. A., Underwood, B. A., & Deckelbaum, R. J. (2005). A life cycle micronutrient perspective for women's health. *The American Journal of Clinical Nutrition*, 81(5), 1188S–1193S. <https://doi.org/10.1093/ajcn/81.5.1188>
- Bellon, M. R., Ntandou-Bouzitou, G. D., & Caracciolo, F. (2016). On-farm diversity and market participation are positively associated with dietary diversity of rural mothers in Southern Benin, West Africa. *PLoS One*, 11(9), e0162535. <https://doi.org/10.1371/journal.pone.0162535>
- Berti, P. R. (2015). Relationship between production diversity and dietary diversity depends on how number of foods is counted. *Proceedings of the National Academy of Sciences*, 112(42):E5656. <https://doi.org/10.1073/pnas.1517006112>
- Boedecker, J., Termote, C., Assogbadjo, A. E., Van Damme, P., & Lachat, C. (2014). Dietary contribution of wild edible plants to women's diets in the buffer zone around the Lama forest, Benin—An underutilized potential. *Food Security*, 6(6), 833–849. <https://doi.org/10.1007/s12571-014-0396-7>
- Coates, J., Swindale, A., & Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for measurement of food access: Indicator guide (Version 3; FANTA III. Food and Nutrition Technical Assistance)*. USAID.
- Custodio, E., Kayitakire, F., Fortin, S., Thomas, A. C., Kameli, Y., Nkuzimana, T., Ndiaye, B., & Martin-Prevel, Y. (2020). Minimum dietary diversity among women of reproductive age in urban Burkina Faso. *Maternal & Child Nutrition*, 16(2), 12897. <https://doi.org/10.1111/mcn.12897>
- Custodio, E., Kayitakire, F., & Thomas, A. (2015). *Exploring the new indicator minimum dietary diversity-women. Results from Burkina Faso*. Retrieved from Joint Research Centre European Commission website <https://ec.europa.eu/jrc>
- Darnton-Hill, I., & Mkpuru, U. (2015). Micronutrients in pregnancy in low- and middle-income countries. *Nutrients*, 7(3), 1744–1768. <https://doi.org/10.3390/nu7031744>
- Development Initiatives Poverty Research Ltd. (2022). *2021 Global nutrition report. The state of global nutrition*.
- EuropeAid. (2015). *Action plan on nutrition. Reducing the number of stunted children under five by 7 million by 2025*. Directorate General International Cooperation and Development. <https://op.europa.eu/en/publication-detail/-/publication/6b8b10e4-c103-42d7-ae08-f8604ae8dfab/>
- EuropeAid. (2021). *Programme Sécurité Alimentaire et Nutritionnelle (SAN) TD/FED/038-874—Composante Sécurité Alimentaire (EuropeAid/170919/IH/ACT/TD)*. <https://webgate.ec.europa.eu/online-services/#/>
- FAO. (2016). *Minimum Dietary Diversity for Women. A guide to measurement*.
- FAO. (2021). *Minimum dietary diversity for women: An updated guide to measurement—From collection to action*. Food & Agriculture Org.
- Food and Agriculture Organization of the United Nations. (2023). *GIEWS—Global information and early warning system country brief—Chad*. <https://www.fao.org/giews/countrybrief/country.jsp?code=TC>
- FSIN and Global Network Against Food Crises. (2023). *GRFC 2023*.
- Gaillard, C., Verger, E. O., Dury, S., Dop, M. C., & El Ati, J., MEDINA Study Group. (2022). Farm production diversity and women's dietary diversity: Evidence from central Tunisia. *PLoS One*, 17(2), e0263276. <https://doi.org/10.1371/journal.pone.0263276>
- Gitagia, M. W., Ramkat, R. C., Mituki, D. M., Termote, C., Covic, N., & Cheserek, M. J. (2019). Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food & Nutrition Research*, 63. <https://doi.org/10.29219/fnr.v63.1553>
- Huang, M., Sudfeld, C., Ismail, A., Vuai, S., Ntwenya, J., Mwanyika-Sando, M., & Fawzi, W. (2018). Maternal dietary diversity and growth of children under 24 months of age in rural Dodoma, Tanzania. *Food and Nutrition Bulletin*, 39(2), 219–230. <https://doi.org/10.1177/0379572118761682>
- INSEED. (2009). *Deuxieme recensement general de la population et de l'habitat: RGPH2 2009*. Institut national de la statistique, des études économiques et démographiques (Chad).
- Integrated Food Security Phase Classification. (2021). Tchad: Analyse IPC de la malnutrition aigüe, octobre 2020-septembre 2021. <https://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1154849/?iso3=TC>

- Jones, A. D., Creed-Kanashiro, H., Zimmerer, K. S., de Haan, S., Carrasco, M., Meza, K., Cruz-Garcia, G. S., Tello, M., Plasencia Amaya, F., Marin, R. M., & Ganoza, L. (2018). Farm-level agricultural biodiversity in the Peruvian Andes is associated with greater odds of women achieving a minimally diverse and micro-nutrient adequate diet. *The Journal of Nutrition*, 148(10), 1625–1637. <https://doi.org/10.1093/jn/nxy166>
- Lourme-Ruiz, A., Dury, S., & Martin-Prével, Y. (2021). Linkages between dietary diversity and indicators of agricultural biodiversity in Burkina Faso. *Food Security*, 13(2), 329–349. <https://doi.org/10.1007/s12571-020-01137-5>
- Ludwig, T. (2018). *An egg for an egg and a bean for a bean? How production diversity determines dietary diversity of smallholder farmers in rural India* (SSRN Scholarly Paper 3098283). <https://doi.org/10.2139/ssrn.3098283>
- Magurran, A. E., & McGill, B. J. (2011). *Biological diversity: Frontiers in measurement and assessment*. Oxford University Press.
- Melby, C. L., Orozco, F., Averett, J., Muñoz, F., Romero, M. J., & Barahona, A. (2020). Agricultural food production diversity and dietary diversity among female small holder farmers in a region of the Ecuadorian Andes experiencing nutrition transition. *Nutrients*, 12(8), 2454. <https://doi.org/10.3390/nu12082454>
- Muthini, D., Nzuma, J., & Nyikal, R. (2020). Farm production diversity and its association with dietary diversity in Kenya. *Food Security*, 12(5), 1107–1120. <https://doi.org/10.1007/s12571-020-01030-1>
- Ochieng, J., Afari-Sefa, V., Lukumay, P. J., & Dubois, T. (2017). Determinants of dietary diversity and the potential role of men in improving household nutrition in Tanzania. *PLoS One*, 12(12), e0189022. <https://doi.org/10.1371/journal.pone.0189022>
- OXFAM. (2016). *Atlas de la Vulnérabilité dans le Guéra*. [https://www.prospect-cs.be/wp-content/uploads/2016/12/Atlas-Guera-Partie-1\\_v2016.pdf](https://www.prospect-cs.be/wp-content/uploads/2016/12/Atlas-Guera-Partie-1_v2016.pdf)
- Powell, B., Thilsted, S. H., Ickowitz, A., Termote, C., Sunderland, T., & Herforth, A. (2015). Improving diets with wild and cultivated biodiversity from across the landscape. *Food Security*, 7(3), 535–554. <https://doi.org/10.1007/s12571-015-0466-5>
- Roba, K. T., O'Connor, T. P., O'Brien, N. M., Aweke, C. S., Kahsay, Z. A., Chisholm, N., & Lahiff, E. (2019). Seasonal variations in household food insecurity and dietary diversity and their association with maternal and child nutritional status in rural Ethiopia. *Food Security*, 11(3), 651–664. <https://doi.org/10.1007/s12571-019-00920-3>
- Singh, S., Jones, A. D., DeFries, R. S., & Jain, M. (2020). The association between crop and income diversity and farmer intra-household dietary diversity in India. *Food Security*, 12(2), 369–390. <https://doi.org/10.1007/s12571-020-01012-3>
- World Health Organization. (2014). *Global nutrition targets 2025: Policy brief series*. (Policy Brief WHO/NMH/NHD/14.2).

## SUPPORTING INFORMATION

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

**How to cite this article:** Mascareñas-García, M., Custodio, E., Issa, M. G., Bechir, M., & Kayitakire, F. (2025). Increased food crop diversification and gathering of wild plants associated with women's dietary diversity in Chad. *Maternal & Child Nutrition*, 21, e13697. <https://doi.org/10.1111/mcn.13697>