**Original Research Article**

**Hidden Hunger in Sahelian Cities - Nutrient Adequacy and Food Security in Urban Mali**

**Abstract**

**Background**: In Mali, rapid urbanization has led to increasing food security challenges, but research on urban dietary patterns is limited. The objective of this analysis is to assess food security, dietary diversity and the associated socio-demographic determinants of Bamako households, between 2018 and 2022.

**Methods**: We analyzed 5,792 households based on data from the National Food Security and Nutrition Survey (ENSAN) in Mali with descriptive statistics, bivariate, and multivariable logistic regression. Primary predictors were Household Dietary Diversity Scores (HDDS), Food Consumption Scores (FCS), and wealth quintiles

**Results**: The household diet was cereal-based (99.3%) and largely devoid of protein-rich foods such as eggs (20.1%) and legumes (36.7%). We found a significant decrease in the prevalence of food security between 2018 (64.5%) and 2022 (59.2%) (p<0.01). Several important predictors of HHFS status were found in the multivariable regression. Urban and higher education were identified as strong positive predictors (AOR 1.8, CI:1.4-2.3 and AOR=2.1, CI:1.7–2.6, respectively), indicating associations between urban and being well-educated with better access to and use of food. On the other hand, households with the least wealth quintile (AOR=0.4, 95% CI:0.3-0.6) and polygamous family structures (AOR=0.7, 95% CI:0.5-0.9) witnessed a significant decrease in food security, thus pinpointing the combined burden of economic and complex household-based adversities. The findings emphasize the importance of targeted interventions directed to the socioeconomic and cultural dimensions of food insecurity.

**Conclusion**: The food insecurity of Bamako, however, was resultant of economic instability and educational imbalances even though there is fair dietary diversity. Policy responses must incorporate urban farming, nutrition-sensitive social protection and gender-sensitive instruction programs.

**Keywords**: Food security, dietary diversity, urban households, Mali, ENSAN, socio-demographic determinants

**Introduction**

Food security is attained when every single individual has consistent and affordable access to sufficient safe, nutritive food to meet their dietetic requests and personal preferences, guaranteeing an active and healthy lifestyle at all times1. The Volta region of Mali, a Sahelian land-locked country in West Africa, faces chronic food insecurity induced by a combination of climate-triggered shocks, political instability and economic fragility2 (FAO, 2021). The capital city, Bamako, has been urbanized rapidly until the period 1987 to 2009 with an annual rate of 4.9% and somewhat moderated but still high of the order of 4.5% in recent years 3. In 2023, the city’s population surpassed 3 million inhabitants, of whom approximately 65–70% resided in informal settlements (un-habitat, 2022; INS Mali projections)4,5. This urban pressure has put a strain on food systems, increasing food security and nutrition challenges in a situation where most people already have unreliable access to essential services6.

The urban poor of Bamako are especially vulnerable due to high levels of reliance on market-purchased foods, so that these account for over 80% of the city dwellers’ dietary source of consumption7,8 . If stability in millet (especially) and rice prices is achieved, household food security is likely to be greatly enhanced9,10. In addition, the nutrition transition resulting from urbanization has given rise to both undernutrition and the emergence of overweight and obesity, thus leading to a double burden of malnutrition11,12.

Despite being the focus of some research, there is a dearth of information on urban food systems and their particular challenges in Mali. Most studies to date have concentrated on agricultural production sides with little concern about urban consumption patterns and their nutritional implications6,13 . It’s an oversight that is particularly worrisome in Mali, where 4.9% of the country’s population is urbanizing each year, and its urban population is increasingly concentrated in cities like Bamako8,14.

This paper seeks to fill three major knowledge gaps with implications for food security policy and programming. We look, first, at dietary change in urban areas, asking how processes of urbanization shape diet patterns and nutritional outcomes. Second, we look at major socio-economic factors that determine food security, including education attainment, marital status, and wealth status, and how these conditions work differently in the rural and urban settings. Third, we aim for policy relevance by considering effective interventions that mirror Sustainable Development Goal 2 (Zero Hunger), specifically including urban-based solutions15.

The timeframe of the study (2018–2022) corresponds to a period of Mali’s development characterized by years of political transition and economic crises since the coup d’état in 2020. We can thus look at how these macro-level changes have influenced household food security in Bamako. Results of our analysis have implications not only for policymakers in Mali but also for those interested in supporting urban food systems across similarly Sahelian landscapes grappling with similar urbanization and food security challenges.

Addressing these research lacunae, this study seeks towards adding to the knowledge based on the food security dynamics in the urban areas of Mali in a more nuanced way, transit from the customary rural-centered approach, which has tended to dominate the Malian (urban) food security literature. The generated evidence will be of specific use for the design of targeted interventions to which interventions are the needs of urban inhabitants compared with national and regional food security objectives.

**Methods**

**Study Design and Data Source**

This analysis is based on Malian National Food Security and Nutrition Survey (ENSAN) data, collected biannually in a cross-sectional survey by the government’s Early Warning System (SAP) with partners, including WFP, FAO, UNICEF16. The survey uses a two-stage cluster sample design which provides national level representation and makes it possible to analyze data at the regional and district level17.

We restricted our analysis to the data from Bamako District, which is divided into 6 communal districts with different social economic profiles. The sample comprised 5,792 households surveyed between 2018 and 2022, and annual sample sizes varied from 444 households in 2018 to 1,963 in 2020 (Table 1).

**Table 1. Distribution of Surveyed Households by Year**

|  |  |  |
| --- | --- | --- |
| Year | Number of Households | Percentage |
| 2018 | 444 | 7.7% |
| 2019 | 1,504 | 26.0% |
| 2020 | 1,963 | 33.9% |
| 2021 | 1,242 | 21.4% |
| 2022 | 639 | 11.0% |
| Total | **5,792** | **100%** |

**Variables and Indicator**

The study used two main outcome variables to adequately measure both household food security and nutrition status. First, the status of food security was assessed using the validated Household Food Insecurity Access Scale (HFIAS) that classifies households into four levels of food security according to their experience of food insecurity. The categories include very low food security (no food access problems of any kind) with very high food insecure (at least one person in the household was food insecure to the extent that they had inadequate food)18. This graduated scale adds nuance by providing a range of levels of food insecurity that urban households experience19,20.

Second, dietary diversity was examined through two complementary indicators which proxy for different aspects of household food consumption patterns21. The Food Insecurity Experience Scale (FIES)-based Food Insecurity index (FHI) is a measure developed by the Food and Agriculture Organization of the United Nations (FAO) in 2010 as part of the Voices of the Hungry (VoH) project22,23.The FHI captures access and affordability (not just production), reflects real-life experiences rather than just economic or agricultural data24. The Household Dietary Diversity Score (HDDS) covers the HOW-WHAT, which is the count of different food groups consumed by the household members over a 24-hour recall period which offers a snapshot of the diversity of the household diet25,26. Additionally, the Food Consumption Score (FCS) provides a more holistic evaluation by considering both the consumption frequency and dietary significance of different food groups27,28. As such, these two measures offer a strong characterization of the quantity and quality of dietary intake patterns of Bamako household, facilitating more targeted nutritional interventions.

**Predictor Variables**

A wide range of socio-demographic and economic factors were considered to explore their effects on food security and diet diversity among households in Bamako.

Household Characteristics

Urban vs. rural place of residence was one of the primary identifiable household-level variables, given that it is possible that urban households and rural households experience different food access dynamics29. The number of members in the household size was also examined to ascertain if greater household size had influenced food security. Furthermore, age, gender and the education level of the head of the household were considered since they are likely to have affected stability of income, food purchase decisions and nutritional knowledge30,31. Marital status was coded as monogamous, polygamous, single and widowed households, since family setup might have an influence on resource allocation and household food sharing32.

**Table 2. Household Dietary Diversity Score (HDDS)**

|  |  |
| --- | --- |
| Food Group | Description |
| 1. Cereals | Rice, wheat, maize, millet, sorghum, bread, pasta, etc. |
| 2. Roots & Tubers | Potatoes, yams, cassava, sweet potatoes, etc. |
| 3. Vegetables | Leafy greens, tomatoes, carrots, onions, etc. (fresh or cooked). |
| 4. Fruits | Fresh or dried fruits (e.g., mangoes, bananas, apples). |
| 5. Meat, Poultry & Offal | Beef, chicken, goat, liver, etc. |
| 6. Eggs | Chicken, duck, or other eggs. |
| 7. Fish & Seafood | Fresh, dried, or canned fish/shellfish. |
| 8. Pulses, Legumes & Nuts | Beans, lentils, peanuts, peas, soy products, etc. |
| 9. Milk & Dairy Products | Milk, cheese, yogurt, or other dairy (excludes butter). |
| 10. Oils & Fats | Cooking oils, butter, margarine, or fat-rich foods. |
| 11. Sugar & Honey | Sugar, sweets, or honey. |
| 12. Spices, Condiments & Beverages | Tea, coffee, spices |

Scoring (1 if consumed, 0 if not).

The maximum attainable HDDS score, 12, reflects the consumption from all 12 food groups, over 24 h recall period (Table2)28. Scores are interpreted consistently: scores of 4 or less indicate low dietary diversity, which is indicative of low dietary variety and possibly food insecurity. 5–6 food-group scores indicate the medium level of diversity, indicating the average availability of mixed foods while still missing some major sources of nutrients26. Households that consume 7 or more food groups fall on the category of high dietary diversity, indicating good dietary quality and a wider access to different types of foods, a phenomenon that is related to better nutritional outcomes33. This score system promotes the rapid examination of household food access and dietary quality in food security surveys and nutritional programs.

**Economic Status**

Economic well-being was ascertained by a wealth index. Wealth quintiles (poorest, poor, middle, rich, richest) were used to assess inequalities in food access among the households34. Main sources of income were also measured as income-earning activities to determine a household’s capacity to access a variety of foods and other nutrients35.

**Temporal Factors**

Considering the dynamic nature of food security, this analysis also controlled temporal variations: the survey year was used to monitor changes over time across the years from 2018 to 2022 as a response to the political and economic shock of the 2020 coup and the global fluctuation in food prices. Seasonal variations were likewise controlled for, since food prices and availability in Mali usually vary depending on the lean or abundant season, consequently determining households’ consumption patterns. With those measurements combined, this study can insightfully address multiple dimensions of food security in urban Mali, offering suggestions for context-specific policy measures36,37.

**Data Analysis**

**Statistical Approach**

The study applied a comprehensive tri-level analytical approach to comprehensively assess the links between socio-economic determinants and food security in Bamako households.

Descriptive statistics were first calculated to obtain a full description of the data set. This formative analysis involved computing frequencies and percentages for categorical variables and calculating means and standard deviations for continuous variables. These data enabled an initial profile to be formed of the demographics, dietary patterns and food security situation of households in the study areas.

Second, bivariate analyses were performed to examine crude associations between main variables. An x2 tests were used when comparing relationships between categorical outcomes, (e.g., marital status, food security categories). T-tests were used to compare two groups, and ANOVA was performed to compare multiple groups for continuous variables. We also assessed temporal trends during the study period (2018-2022) to explore the dynamics of food security and dietary diversity over time.

Thirdly, the multivariate analysis was used to determine independent effects of different predictors after adjusting for the potential confounders. A logistic regression model was used to determine what significant factors associated with food security status, urban-rural differences, education level attained, and wealth quintiles were focused on. Models produced odds ratios adjusted for all other predictors (AOR) with 95% confidence intervals, providing strong evidence of effect size for each predictor variable. All quantitative analyses were run in SPSS Version 26 (IBM). Statistical significance throughout testing was set at the conventional level of p<0.05 to allow for strict interpretation of findings.

**Ethical Considerations**

The ENSAN was approved by Mali's National Ethics Committee. Field teams sought verbal consent from all participating households38. Data were de-identified to assure confidentiality of the participant and access allowed only to the authorized researcher.

**Results**

**Household Characteristics**

Important demographic characteristics in the Bamako population were identified in the study (Table 3). The type of habitat was predominantly urban (88.8%), with 11.2% of the households surveyed in peri-urban and rural parts of the district. The proportion of women-headed households was 24.3% of survey respondents in 2022, a nonsignificant increase from 22.1% in 2018 (p=0.12).

**Table 3. Socio-demographic Characteristics of Surveyed Households**

|  |  |  |  |
| --- | --- | --- | --- |
| Characteristic | 2018 (%) | 2022 (%) | p-value |
| Urban residence | 86.5 | 88.8 | 0.03 |
| Female-headed | 22.1 | 24.3 | 0.12 |
| Education of household head |  |  | <0.001 |
| - None | 31.1 | 21.3 |  |
| - Primary | 28.4 | 25.6 |  |
| - Secondary | 11.3 | 16.9 |  |
| - Tertiary | 10.6 | 21.9 |  |
| Marital status |  |  | 0.02 |
| - Monogamous | 68.2 | 65.4 |  |
| - Polygamous | 18.9 | 20.1 |  |
| - Single/Widowed | 12.9 | 14.5 |  |

The education level of the head of households significantly increased during the study period. Those with tertiary education increased by more than two-fold, from 10.6% in 2018 to 21.9% in 2022 (p<0.001). But in 2022, 21.3% of household heads were still not formally educated.

**Dietary Patterns and Food Consumption**

There was a high consumption of staple foods demonstrated by 99.3% of households consuming cereals 24 hours prior to the survey (Table 4). Protein intake from protein-rich foods was low, and particularly for eggs (20.1%) and legumes (36.7%). These trends changed little between 2018 and 2022.

**Table 4. Food Consumption Patterns in Bamako Households**

|  |  |  |
| --- | --- | --- |
| Food Group | Consumed (%) | Not Consumed (%) |
| Cereals | 99.3 | 0.7 |
| Tubers & roots | 26.7 | 73.3 |
| Vegetables | 65.4 | 34.6 |
| Fruits | 35.7 | 64.3 |
| Meat | 43.9 | 56.1 |
| Eggs | 20.1 | 79.9 |
| Fish | 29.1 | 70.9 |
| Legumes | 36.7 | 63.3 |
| Milk/dairy | 45.4 | 54.6 |
| Oils/fats | 93.1 | 6.9 |
| Sugar | 87.6 | 12.4 |
| Spices | 97.6 | 2.4 |

The dietary diversity scores indicated that 82.5% of the households had high dietary diversity (intake of ≥6 types of food groups), whereas 0.9% had low dietary diversity (≤3 groups). But these aggregate numbers hide important differences. Households in the top quintile of the wealth distribution had a significantly higher dietary diversity score than those in the bottom quintile - 7.8 vs 5.2 mean food groups consumed (p<0.001).

**Food Security Status**

The survey inquired regarding food security trends (Table 5). The prevalence of food-secure households significantly decreased from 64.5% in 2018 to 59.2% in 2022 (p=0.008). Moderate food insecurity also grew from 29.7% to 35% during the same time frame with mild food insecurity seeing a parallel increase from 25.1% to 32.1%.

**Table 5. Food Security Status Over Time**

|  |  |  |  |
| --- | --- | --- | --- |
| Food Security Category | 2018 (%) | 2022 (%) | p-value |
| Food secure | 64.5 | 59.2 | 0.008 |
| Mildly insecure | 25.1 | 32.1 | 0.01 |
| Moderately insecure | 7.3 | 5.6 | 0.15 |
| Severely insecure | 3.1 | 3.2 | 0.89 |

Disparities across the communes of Bamako were observed by spatial analysis. Commune VI (the most populous) had the highest percentage of food-insecure households (27.3%) and Commune III, where the neighborhoods are the most affluent, had the lowest percentage of food-insecure households (18.1%).

**Determinants of Food Security**

There were a number of significant predictors of food security via multivariate logistic regression (Table 6). Urban place of residence continued to be highly protective (AOR = 1.8; 95% CI: 1.4 - 2.3), as was higher education (AOR = 2.1; 95% CI: 1.7 - 2.6). The relationship between wealth and food security was dose-response; households in the highest wealth quintile were 3.2 times more likely to be food secure than those in the lowest quintile (95 per cent CI 2.5-4.1).

**Table 6. Multivariate Analysis of Food Security Determinants**

|  |  |  |  |
| --- | --- | --- | --- |
| Factor | Adjusted OR | 95% CI | p-value |
| Urban residence | 1.8 | 1.4-2.3 | <0.001 |
| Tertiary education | 2.1 | 1.7-2.6 | <0.001 |
| Wealth (highest quintile) | 3.2 | 2.5-4.1 | <0.001 |
| Polygamous household | 0.7 | 0.5-0.9 | 0.02 |
| Female-headed household | 0.9 | 0.7-1.1 | 0.32 |

Polygamous homes, which are likely to share a single resource between multiple households, were significantly associated with moderate levels of FNS (AOR: 0.7, 95% CI: 0.5–0.9). There were no differences in food security transition for female-headed households, compared to male-headed households (AOR: 0.9, 95% CI: 0.7-1.1).

**Discussion**

The analysis emphasizes several findings related to urban food security in Bamako. Dietary diversity seems relatively high a priori, as 82.5% of the respondents consume at least six food groups, but a closer view shows that this is largely due to staple cereals, oils and spices rather than nutrient-rich food like animal protein, fruits and vegetables. This is consistent with the idea of “hidden hunger” in which energy intake may be adequate but there are deficiencies at the micronutrient level39 .

A decrease in food security from 64.5% in 2018 to 59.2% in 2022 probably relates to multiple pressures, including the economic consequences of political instability in Mali subsequent to the coup in 2020, global food price shocks brought on by the COVID-19 pandemic and the war in Ukraine, and climate-driven disruptions to agriculture production and market supplies40.

The complementary trend analysis (Figure S1) supports our finding of worsening food security (64.5% to 59.2%) yet suggests a nonlinear trend: a large decrease in 2020 (−8.2%) concurrent with the political transition in Mali and global supply chain disruptions, and partial recovery by 2022. This is consistent with the wealth quintile information (Figure S2) indicating that on average the "poorest" expanded from 18.3% to 22.7% during the same period and emphasizes the manner in which macroeconomic shocks intensify urban poverty. Households in the "riches" quintile in fact experienced no change in dietary diversity (mean number of food groups = 7.8), while the poorest quintile experienced a decrease (5.2 to 4.9 groups), even though income protects from shocks at the systemic level and narrowing (though not eliminating) nutritional gradients.

Figure S3 shows the explosive demographic change. The proportion that tertiary education held in family heads was doubled (10.6 to 21.9), which corresponded to our regression findings (AOR=2.1 for tertiary education). But the fact that 21.3% of Indian households still have unlettered leaders in 2022 indicates a legacy of inequities. This discrepancy might elucidate why the reduction in food insecurity was clustered in richer communes (i.e., Commune III relative to VI), at the intersection of schooling level and wealth. Specific adult educational interventions and targeting women in particular (24.3% of the household heads in 2022), could enhance the protective effects of education seen in our models.

Changing diets and hidden hunger, (Figure S4) illustrates also the lack of progression dietary transition in the consumption of nutrient-rich foods (e.g., eggs: 20.1%; legumes: 36.7%), with high cereal intake (99.3%). This is consistent with (and supportive of) the "hidden hunger" hypothesis in which caloric sufficiency hides the adequacy gap between calories and micronutrients39. It is reassuring that these patterns persisted between 2018 and 2022, and that market interventions (for example, subsidies for legumes, fortification) should be targeted, in combination with production-based approaches, such as urban agriculture.

The study further highlights the powerful relationship between education and food security and lends credence to human capital theories that underscore the importance of education in increasing health and nutrition knowledge41 . Household heads with higher education may be more health literate and have greater access to formal employment, which may increase the capacity of the household to withstand food insecurity42. Using this evidence, the study suggests three priority interventions for urban food security. First, by bolstering urban food systems, including enhancing urban agriculture (e.g., rooftop farming and micro-gardening), implementing municipal grain reserves to help stabilize costs, and upgrading market conditions in informal settlements. Second, put in place nutrition-sensitive social protection programs such as targeted food subsidies for protein rich foods (eggs, milk, and legumes); integrating a nutrition education component into cash transfers; and diversifying school feeding menus. Third, gender-responsive programming by providing business training and microloans to women food vendors, mitigating cultural barriers that prevent women gaining access to nutritious foods and promoting childcare services to reduce the time burden on working mothers.

Our finding is consistent with and adds to that of other similar studies conducted in Mali, in Africa, and globally. In Mali, things?? like Macalou et al. 6 and Agbendech et al. 43 have drawn attention to the threats of urbanization for diets via their associated dependency on market-purchased foods and consumption of cereal-based diets that align with findings on low protein intake and ‘hidden hunger’ in Bamako. In other parts of Africa, studies in Ethiopia19 and Burkina Faso44 have also reported wealth and education as key predictors of food security, which parallels our results regarding protective effects of higher education (AOR = 2.1) and urban residency (AOR = 1.8). Internationally, the measures of the RHS and HDS used in this study are commonly in use, for example in the work of Cafiero et al. (2018)22, supporting its application for cross-context comparisons. However, what distinguishes this study from other existing literature is that it provides a rare analysis of the time-dependence of political and economic shocks (e.g., the 2020 coup) on urban food security. Although similarities can be found between this and urbanization, and nutrition transition studies45, our identifying polygamous households as a risk factor (AOR = 0.7) brought unique perspectives on socio-cultural causes of food insecurity in Sahelian cities.

There are some limitations to the study despite its richness of insight. Its cross-sectional nature does not allow causal inferences to be drawn, and self-reported data may underestimate snack foods and street foods, which could result in certain errors in dietary evaluations46,47. Furthermore, although the HFIAS is an established tool, there is a possibility that it does not capture culturally specific dimensions of food insecurity in urban Mali48. Another potential limitation for trend estimation is variability in the number of individuals sampled in different years49. Longitudinal designs should be used for future research to better assess change over time, and direct measures of dietary intake should be utilized to enhance precision along with mixed methods to further understand the urban food environment50. These advances would give scientific findings more robustness and make policy intervention more efficient.

**Conclusion**

This large cross-sectional study of Bamako households over 2018 to 2022 highlighted enduring food insecurity and undernutrition, despite moderate diversity of diets. Urban dwelling, education and wealth were still main factors significantly associated with household food security whereas living in polygamous family was observed to be a risky factor. The results also highlight the importance of multi-sectoral approaches of agricultural, social protection and education policies.

The additional trends further underscore the need for adaptive social protection. For example, the 2020 deterioration in food security warrants crisis-mitigating actions (emergency grain reserves, price regulations) in times of political or economic turmoil. On the other hand, the continuous increase in education provides an opportunity towards long-term sustainability; the integration of nutrition education into vocational training pro-grammes can capitalize on this rise.

As Mali advances through its urban transformation, promoting resilient urban food systems will be essential to realize Sustainable Development Goal 2 and secure nutrition for all city inhabitants. Further, longitudinal research should aim to understand why rich families managed to keep their diet diversity during shocks (Figure 2) and how polygamous nature can worsen food insecurity (AOR=0.7). Mixed-method studies may also situate the quantitative trends on a continuum by including cultural perspectives on food sharing or gendered decision-making in polygynous households.

**List of Abbreviations**

|  |  |
| --- | --- |
| Abbreviation | Full Form |
| ENSAN | National Food Security and Nutrition Survey (Enquête Nationale sur la Sécurité Alimentaire et Nutritionnelle) |
| HDDS | Household Dietary Diversity Score |
| FCS | Food Consumption Score |
| HFIAS | Household Food Insecurity Access Scale |
| FIES | Food Insecurity Experience Scale |
| FHI | Food Insecurity Index |
| SAP | Early Warning System (Système d’Alerte Précoce) |
| WFP | World Food Programme |
| FAO | Food and Agriculture Organization |
| UNICEF | United Nations Children’s Fund |
| AOR | Adjusted Odds Ratio |
| ANSSA | National Agency for Food Safety |
| CI | Confidence Interval |
| SDG | Sustainable Development Goal |
| INSP | National Institute of Public Health (Institut National de Santé Publique) |

**Availability of data and materials:**

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request. The data were sourced from the National Food Security and Nutrition Survey (ENSAN) conducted by Mali’s Early Warning System (SAP) in collaboration with partners such as WFP, FAO, and UNICEF.

**Ethics considerations:**

**Ethics approval**: This study utilizes de-identified data from the ENSAN survey, which was approved by Mali’s National Ethics Committee. No additional ethical approval was required for this secondary analysis.

**Consent to participate**: Not applicable, as the study involved secondary analysis of existing data without direct participant recruitment.

**Consent for publication**: Not applicable, as the manuscript does not contain identifiable individual-level data. All data were anonymized and handled in compliance with institutional and national ethical guidelines.

**References**

1. Pérez-Escamilla R. Food Security and the 2015-2030 Sustainable Development Goals: From Human to Planetary Health: Perspectives and Opinions. *Curr Dev Nutr*. 2017;1(7):e000513. doi:10.3945/cdn.117.000513

2. Tucker L. Climate Vulnerabilities and Food Insecurity in Mali. Published online July 19, 2023. Accessed June 26, 2025. https://www.elibrary.imf.org/view/journals/018/2023/054/article-A001-en.xml

3. How Can Bamako Become an Engine of Growth & Service Delivery? Tackle Urban and Institutional Fragmentation. World Bank. Accessed June 26, 2025. https://www.worldbank.org/en/country/mali/publication/how-can-bamako-become-an-engine-of-growth-service-delivery-tackle-urban-and-institutional-fragmentation

4. INSTAT. Résultats du RGPH5. Institut National de la Statistique du Mali|INSTAT. Accessed June 26, 2025. https://instat-mali.org/fr/actualites-et-evenements/resultats-du-rgph5

5. Bank W. Mali - Bamako Urban Resilience Project. World Bank. Accessed June 26, 2025. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/en/099145011102233804

6. Macalou M, Keita SI, Coulibaly AB, Diamoutene AK. Urbanization and food security: evidence from Mali. *Front Sustain Food Syst*. 2023;7. doi:10.3389/fsufs.2023.1168181

7. Agbendech M, Chauliac M, Gerbouin Rérolle P, Kante N, Malvy DJM. [Food consumption patterns in the urban milieu of Bamako]. *Santé Publique Vandoeuvre-Lès-Nancy Fr*. 2000;12:45-63.

8. Mesplé-Somps S, Robilliard AS, Gakou AD. Urbanisation et ségrégation spatiale à Bamako. *Post-Print*. Published online 2015. Accessed June 26, 2025. https://ideas.repec.org//p/hal/journl/hal-01292721.html

9. Vitale J, Bessler DA. On the discovery of millet prices in Mali. *Pap Reg Sci*. 2006;85(1):139-162. doi:10.1111/j.1435-5957.2006.00068.x

10. Sanga U, Sidibé A, Olabisi LS. Dynamic pathways of barriers and opportunities for food security and climate adaptation in Southern Mali. *World Dev*. 2021;148:105663. doi:10.1016/j.worlddev.2021.105663

11. Urbanisation rapide en Afrique : l’exemple du Mali. World Bank. Accessed December 28, 2024. https://www.banquemondiale.org/fr/news/feature/2017/05/02/rapid-urbanization-in-africa-investing-in-the-development-of-africas-cities

12. Popkin BM, Ng SW. The nutrition transition to a stage of high obesity and noncommunicable disease prevalence dominated by ultra‐processed foods is not inevitable. *Obes Rev*. 2022;23(1):e13366. doi:10.1111/obr.13366

13. Goïta A, Iknane AA, Coulibaly D, et al. Facteurs influençant la consommation alimentaire des ménages de la Région de Tombouctou en Février 2018. *Mali Santé Publique*. Published online December 31, 2019:18-22. doi:10.53318/msp.v9i02.1501

14. Mesplé-Somps S, Selod H, Spielvogel G, Blankespoor B. Urbanisation et croissance dans les villes du Mali. In: Brunet-Jailly J, Charmes J, Konaté D, eds. *Le Mali contemporain*. Hors collection. IRD Éditions; 2014:545-580. doi:10.4000/books.irdeditions.21242

15. GBD 2019 Under-5 Mortality Collaborators. Global, regional, and national progress towards Sustainable Development Goal 3.2 for neonatal and child health: all-cause and cause-specific mortality findings from the Global Burden of Disease Study 2019. *Lancet Lond Engl*. 2021;398(10303):870-905. doi:10.1016/S0140-6736(21)01207-1

16. Rapport de Synthese: Enquête Nationale sur la Sécurité Alimentaire et Nutritionnelle, Février 2020 (ENSAN Mali) - Mali | ReliefWeb. June 4, 2020. Accessed June 26, 2025. https://reliefweb.int/report/mali/rapport-de-synthese-enqu-te-nationale-sur-la-s-curit-alimentaire-et-nutritionnelle-f-0

17. Mali - RAPPORT DEFINITIF - Enquête nationale sur la sécurité alimentaire et nutritionnelle, septembre 2015 (ENSAN Mali). Accessed June 26, 2025. https://microdata.instat.ml/index.php/catalog/49/get-microdata

18. Hussein FM, Ahmed AY, Muhammed OS. Household food insecurity access scale and dietary diversity score as a proxy indicator of nutritional status among people living with HIV/AIDS, Bahir Dar, Ethiopia, 2017. Lightfoot DA, ed. *PLOS ONE*. 2018;13(6):e0199511. doi:10.1371/journal.pone.0199511

19. 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 Nutr*. 2015;1(1):2. doi:10.1186/2055-0928-1-2

20. Salman Md, Haque S, Hossain MdE, Zaman N, Tuj Zohora Hira F. Pathways toward the sustainable improvement of food security: Adopting the household food insecurity access scale in rural farming households in Bangladesh. *Res Glob*. 2023;7:100172. doi:10.1016/j.resglo.2023.100172

21. Sheikomar OB, Dean W, Ghattas H, Sahyoun NR. Validity of the Food Insecurity Experience Scale (FIES) for Use in League of Arab States (LAS) and Characteristics of Food Insecure Individuals by the Human Development Index (HDI). *Curr Dev Nutr*. 2021;5(4):nzab017. doi:10.1093/cdn/nzab017

22. Cafiero C, Viviani S, Nord M. Food security measurement in a global context: The food insecurity experience scale. *Measurement*. 2018;116:146-152. doi:10.1016/j.measurement.2017.10.065

23. Smith MD, Rabbitt MP, Coleman- Jensen A. Who are the World’s Food Insecure? New Evidence from the Food and Agriculture Organization’s Food Insecurity Experience Scale. *World Dev*. 2017;93:402-412. doi:10.1016/j.worlddev.2017.01.006

24. Jones AD, Ngure FM, Pelto G, Young SL. What Are We Assessing When We Measure Food Security? A Compendium and Review of Current Metrics. *Adv Nutr*. 2013;4(5):481-505. doi:10.3945/an.113.004119

25. Mekonnen DA, Talsma EF, Trijsburg L, et al. Can household dietary diversity inform about nutrient adequacy? Lessons from a food systems analysis in Ethiopia. *Food Secur*. 2020;12(6):1367-1383. doi:10.1007/s12571-020-01056-5

26. del Valle M M, Shields K, Boza S. Using Household Dietary Diversity Score and Spatial Analysis to Inform Food Governance in Chile. *Nutrients*. 2024;16(17):2937. doi:10.3390/nu16172937

27. Ouedraogo O, Compaore E, Amouzou E, Augustin Z, Dicko M. Household’s Food Consumption Profile during Agricultural Mitigation Period: Burkina Faso Centre-West Region Case. *J Nutr Food Secur*. 2019;4. doi:10.18502/jnfs.v4i4.1726

28. Matavel C, Hoffmann H, Rybak C, Steinke J, Sieber S, Müller K. Understanding the drivers of food security among agriculture-based households in Gurué District, Central Mozambique. *Agric Food Secur*. 2022;11(1):7. doi:10.1186/s40066-021-00344-3

29. Haile Aboye B, Gebre-Egziabher T, Kebede B. Peri-urban food insecurity and coping strategies among farm households in the face of rapid urbanization in Sub-Saharan Africa: Evidence from Ethiopia. *Res Glob*. 2024;8:100200. doi:10.1016/j.resglo.2024.100200

30. Caswell JA, Yaktine AL, Allotments C on E of the A of FR and S, et al. Individual, Household, and Environmental Factors Affecting Food Choices and Access. In: *Supplemental Nutrition Assistance Program: Examining the Evidence to Define Benefit Adequacy*. National Academies Press (US); 2013. Accessed June 26, 2025. https://www.ncbi.nlm.nih.gov/books/NBK206912/

31. Vo DH, Vo AT, Ho CM. Does gender and education of the households’ heads matter for wealth accumulation in Vietnam? Evidence from a recent decade. *Heliyon*. 2023;9(12):e22836. doi:10.1016/j.heliyon.2023.e22836

32. Boltz M, Chort I. The Risk of Polygamy and Wives’ Saving Behavior. *World Bank Econ Rev*. 2019;33(1):209-230. doi:10.1093/wber/lhw054

33. IndiKit. Individual Dietary Diversity Score. IndiKit. Accessed June 26, 2025. https://www.indikit.net

34. Baffa LD, Mengistu B, Desta F. Decomposing socioeconomic inequality in the dietary diversity practice among children aged 6–23 months in Ethiopia. *Sci Rep*. 2025;15(1):17282. doi:10.1038/s41598-025-02366-4

35. Khan J, Mohanty SK. Estimation of household level variation in per capita calorie intake by measures of economic well-being of the household in India. *Trop Med Int Health*. 2025;30(6):481-497. doi:10.1111/tmi.14097

36. Ben Abdallah M, Fekete-Farkas M, Lakner Z. Exploring the Link between Food Security and Food Price Dynamics: A Bibliometric Analysis. *Agriculture*. 2021;11(3):263. doi:10.3390/agriculture11030263

37. Headey D, Bachewe F, Marshall Q, Raghunathan K, Mahrt K. Food prices and the wages of the poor: A cost-effective addition to high-frequency food security monitoring. *Food Policy*. 2024;125:102630. doi:10.1016/j.foodpol.2024.102630

38. SAP : Rapport définitif de l’enquête Nationale sur la Sécurité Alimentaire et Nutritionnelle, Février 2020 (ENSAN MALI) | Food Security Cluster. Accessed June 26, 2025. https://fscluster.org/es/mali/document/sap-rapport-definitif-de-lenquete

39. Yilmaz H, Yilmaz A. Hidden Hunger in the Age of Abundance: The Nutritional Pitfalls of Modern Staple Crops. *Food Sci Nutr*. 2025;13(2):e4610. doi:10.1002/fsn3.4610

40. Diao X, Dorosh PA, Randriamamonjy J, Smart J, Thurlow J. Mali: Impacts of the Ukraine and global crises on poverty and food security. Published online June 23, 2022. doi:10.2499/p15738coll2.135949

41. Egg S, Wakolbinger M, Reisser A, Schätzer M, Wild B, Rust P. Relationship between nutrition knowledge, education and other determinants of food intake and lifestyle habits among adolescents from urban and rural secondary schools in Tyrol, Western Austria. *Public Health Nutr*. 23(17):3136-3147. doi:10.1017/S1368980020000488

42. Mutisya M, Ngware MW, Kabiru CW, Kandala N bakwin. The effect of education on household food security in two informal urban settlements in Kenya: a longitudinal analysis. *Food Secur*. 2016;8(4):743-756. doi:10.1007/s12571-016-0589-3

43. Street food in urban Ghana: a desk-top review and analysis of findings and recommendations from existing literature. CABI Databases. Accessed June 26, 2025. https://www.cabidigitallibrary.org/doi/full/10.5555/20163354214

44. Kabore P, Barbier B, Ouoba P, Kiema A, Some L, Ouedraogo A. Perceptions du changement climatique, impacts environnementaux et stratégies endogènes d’adaptation par les producteurs du Centre-nord du Burkina Faso. *VertigO Rev Électronique En Sci L’environnement*. 2019;19(1). Accessed June 26, 2025. https://www.erudit.org/en/journals/vertigo/2019-v19-n1-vertigo04936/1065432ar/

45. Popkin BM, Ng SW. The nutrition transition to a stage of high obesity and noncommunicable disease prevalence dominated by ultra-processed foods is not inevitable. *Obes Rev*. 2022;23(1):e13366. doi:10.1111/obr.13366

46. Savitz DA, Wellenius GA. Can Cross-Sectional Studies Contribute to Causal Inference? It Depends. *Am J Epidemiol*. 2023;192(4):514-516. doi:10.1093/aje/kwac037

47. Maki KC, Slavin JL, Rains TM, Kris-Etherton PM. Limitations of Observational Evidence: Implications for Evidence-Based Dietary Recommendations. *Adv Nutr*. 2014;5(1):7-15. doi:10.3945/an.113.004929

48. Charamba V, Kazembe LN, Nickanor N. Application of item response theory modelling to measure an aggregate food security access score. *Food Secur*. 2023;15(5):1383-1398. doi:10.1007/s12571-023-01388-y

49. Parsons S, McCormick EM. Limitations of two time point data for understanding individual differences in longitudinal modeling — What can difference reveal about change? *Dev Cogn Neurosci*. 2024;66:101353. doi:10.1016/j.dcn.2024.101353

50. Shim JS, Oh K, Kim HC. Dietary assessment methods in epidemiologic studies. *Epidemiol Health*. 2014;36:e2014009. doi:10.4178/epih/e2014009

**Supplementary Materials**:

Figure1: Trend in food security prevalence in % from 2018 to 2022 in Bamako

Figure 2: Evolution of wealth index quintile in % from 2018 to 2022 in Bamako

Figure3: Changes in the educational attainment of heads of households, 2018–2022 in Bamako

Figure 4: Trends in household food consumption patterns from 2018-2022 in Bamako