

The sustainability of diets in sub-Saharan Africa: Synergies and tradeoffs between human health and the environment

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ABSTRACT

Sub-Saharan Africa (SSA) faces unique food security and sustainability challenges. The diets in SSA are insufficient on average, but how they compare across various population segments in terms of nutritional adequacy and environmental footprints is not sufficiently understood. Life cycle assessment (LCA) of diets can be useful, but existing life cycle inventories mostly refer to high-income countries. Hence, data and methodological adjustments are needed to better reflect local production and consumption conditions. Here, we enhance LCA by tailoring it to local contexts, providing the first comprehensive LCA analysis of diets in SSA, and combining this with nutritional analysis. We assess global warming, land use, and water consumption impacts, as well as nutritional adequacy of diets in Ethiopia, Ghana, and Nigeria. We also analyse associations between the nutritional and environmental dimensions across population segments with a particular focus on the effects of rising incomes and urbanization. While we find variation between countries, average diets in SSA have much lower environmental impacts than the Western dietary pattern in high-income countries. Rising incomes and urbanization in SSA are associated with improved nutrient adequacy, but also with larger environmental footprints, pointing at sustainability tradeoffs under current conditions. These tradeoffs may be reduced through developing and implementing dietary patterns that optimize nutritional, environmental, and social goals. In addition, productivity and efficiency gains in food supply chains are needed to ensure that a variety of healthy food choices is locally available and affordable.

1. Introduction

Transforming food systems is imperative to effectively address the interconnected challenges of food insecurity, malnutrition, and environmental degradation (FAO, 2025; Rockström et al., 2025; Willett et al., 2019; von Braun et al., 2023). According to the latest FAO report on food insecurity and nutrition (FAO et al., 2025), hunger currently affects 8.8% of the global population. Meanwhile, 28% of the population face moderate to severe food insecurity, and 2.6 billion people are unable to afford a healthy diet. The prevalence of obesity is increasing (15.8% of the global population), and for the first time, obesity has surpassed underweight among children and adolescents (FAO et al., 2025; UNICEF, 2025). At the same time, it is estimated that one-third of all global greenhouse gas emissions originate from food systems (Crippa

et al., 2021). In recent decades, approximately one-third of the world's land has been used or changed, with 87% of this land being used for food production (Winkler et al., 2021; Poore and Nemecek, 2018). Around 70% of all freshwater withdrawals are used for agricultural irrigation (Ingrao et al., 2023). Issues of unsustainable food systems exist everywhere, in high-, middle-, and low-income countries, with various manifestations depending on the particular context.

Sub-Saharan Africa (SSA) faces unique food system challenges that require context-specific solutions (Noort et al., 2022). The region is heavily affected by climate change, limited agricultural technology, food insecurity, and high rates of malnutrition (Tapkigen et al., 2024; Shin et al., 2024; FAO et al., 2024). Traditional African diets are characterized by a high intake of starchy staples, such as cereals, roots, and tubers, and a low intake of fruits, vegetables, and animal-sourced foods

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(ASF) (Oniang'o et al., 2025; Hirvonen et al., 2020). Although diets in SSA appear to have a smaller environmental footprint than Western diets due to lower ASF consumption, they often do not meet nutritional requirements due to socioeconomic factors and the higher cost of healthier diets (McCullough et al., 2024; Tuyishimire et al., 2025; Headey et al., 2022). Therefore, smaller environmental footprints of diets in SSA are often primarily a matter of limited food affordability (Li et al., 2024). However, diets in SSA are also evolving quickly due to income growth, urbanization, and other factors, raising concerns about (un)healthy nutrition and increasing environmental footprints in the long run (Tuyishimire et al., 2025; de Vos et al., 2024). As urban populations consume more and tend to have better access to ASF and processed foods, nutritional adequacy may improve, but other types of health and environmental problems might arise (Cockx et al., 2019; Hülsen et al., 2026; Kiribou et al., 2024). Understanding dietary trends under heterogeneous conditions in SSA and their broader implications for sustainable development is vital for evidence-based policymaking (Ameze et al., 2025; Mockshell et al., 2022).

Nevertheless, despite the growing international literature on sustainability assessment of diets, most research concentrates on high-income countries, while Africa remains underrepresented, especially when it comes to evaluating environmental footprints (Green et al., 2021; Tuyishimire et al., 2025). Even the EAT-Lancet Diet 1.0 (Willett et al., 2019), developed to provide a global framework for promoting healthier and more sustainable diets, falls short in addressing issues of applicability, nutrient adequacy, affordability, equity, and inclusivity for populations in different contexts (Marrero et al., 2024). The new EAT-Lancet Diet 2.0 attempts to address some of these issues; however, in terms of dietary composition, little has been changed (Rockström et al., 2025). Food-Based Dietary Guidelines (FBDGs), which were recently developed for some countries in SSA, attempt to set nutritionally adequate standards for local populations, yet without addressing issues of environmental sustainability (Ministry of Food and Agriculture, 2023; Ethiopian Public Health Institute and Ministry of Health, 2022). Very few studies on the environmental impacts of diets focus specifically on the African continent, and those that exist take a very broad regional approach (Green et al., 2021; Tuyishimire et al., 2025; Li et al., 2024) and rely on life cycle assessment (LCA) approaches from high-income countries (Karkour et al., 2021). LCA approaches that explicitly consider typical food production and consumption conditions in SSA do not exist. Nor are we aware of studies that combine nutritional and environmental impacts of SSA diets under various socioeconomic conditions.

Here, we address these knowledge gaps by answering the following two research questions: (1) How can LCA be adapted and improved methodologically to better reflect food production and consumption conditions in SSA? (2) What synergies and tradeoffs between human health (nutrition) and environmental goals exist for dietary change in SSA?

We make two novel contributions to the existing literature, one methodological and one empirical. The methodological contribution involves improving and adjusting life cycle inventories (LCI) for foods produced and consumed in SSA. The empirical contribution involves analyses in three SSA countries, applying context-specific LCA to quantify the environmental footprints of diets under heterogeneous socioeconomic conditions and combining this with nutrition assessments. More specifically, we conduct nutritional LCA, which is defined as a framework combining nutrition assessment with classical LCA-based environmental impact assessment (Heller et al., 2013). We also examine relationships between nutritional adequacy and environmental footprints and evaluate the effects of rising incomes and urbanization on relevant sustainability outcomes. We use nationally representative micro-level data on food consumption from Ethiopia, Ghana, and Nigeria and evaluate the diets of various population segments in terms of nutrient adequacy, global warming, land use, and water consumption.

2. Literature review

We group the existing literature into three main streams: (1) global sustainable diet frameworks, (2) methodological developments in LCA and nutritional LCA, and (3) studies focusing on dietary transitions in SSA and LCA research gaps in this region.

The first stream involves global sustainable diet frameworks, establishing key principles to link human health and the environment. According to the FAO/WHO (2019), a sustainable healthy diet is one that promotes human health and wellbeing, stays within the planetary boundaries, and is accessible and affordable. Scientific research and the political agenda have gradually worked to transform current food systems to make them healthier and more sustainable. The EAT-Lancet Commission on healthy diets has created a framework of scientific targets for healthier and more sustainable diets to be adopted worldwide (Willett et al., 2019). This framework has recently been updated to include a social justice element (Rockström et al., 2025). In the political sphere, the UN Food Systems Summit placed food systems at the heart of the global sustainability agenda, offering strategies and solutions for sustainable transformation (UN, 2021). As a result, a few countries have started to develop their own FBDGs that jointly address health and sustainability concerns (Schäfer et al., 2025). However, in the African context, locally developed FBDGs still lack the environmental perspective (Ministry of Food and Agriculture, 2023; Ethiopian Public Health Institute and Ministry of Health, 2022).

The second stream of research focuses on methodological advances in LCA and nutritional LCA. Different methodologies and indicators can be used to evaluate the sustainability of food systems and diets (Schneider et al., 2023). LCA has become a standard tool for assessing the sustainability of diets, offering flexible options to include various environmental and social dimensions (Paris et al., 2024). Heller et al. (2013) were the first to propose an LCA framework that combines environmental impact assessment with nutrition indicators. This framework incorporates nutritional quality indicators, nutrient profiling, and human health impacts based on epidemiological studies. This approach, which was later termed 'nutritional LCA' (nLCA), has been used in several recent studies to assess diets and foods (Mazac et al., 2023; van Eijdsen et al., 2025). However, most LCA research on diet sustainability has been conducted in high-income countries (Paris et al., 2022; Bunge et al., 2024), where dietary patterns and food supply chains are often quite different from those in low- and middle-income countries. LCA research on diets in SSA is very limited (Noort et al., 2022). A recent perspective article highlighted the relevance of nLCA for Africa and Asia but also stressed important local and regional data gaps and urgent needs for further methodological improvements (McAuliffe et al., 2026).

The third stream focuses on dietary patterns, food system transitions, and LCA-related data gaps in SSA. LCA depends on environmental impact data and LCI that reflect local production and consumption patterns, and such data and inventories are not well developed for SSA (Tuyishimire et al., 2025; Karkour et al., 2021). These gaps persist largely due to the high cost of primary data collection, the fragmented nature of food supply chains in SSA, fewer research groups working on this topic in the region, and limited incentives for private companies to compile and share LCI data (Karkour et al., 2021; McAuliffe et al., 2026). Moreover, diets across SSA vary by country, income level, and degree of urbanization, among other factors. While the diets in rural areas are often dominated by starchy staple foods, urban diets in SSA are increasingly diverse and Westernized (Ameze et al., 2025; Casari et al., 2022). The few existing studies on diet sustainability in SSA tend to be highly aggregated, ignoring regional and socioeconomic variation (Pretorius et al., 2025). More integrated research in various local and regional contexts is needed as a knowledge base for making food systems more sustainable (Biesbroek et al., 2023; Bunge et al., 2024; Qaim et al., 2024; Suarez and Ume, 2024). In this study, we address this need by adapting LCA methods and inventories to SSA conditions and analysing

synergies and tradeoffs of dietary change, considering various relevant sustainability dimensions.

3. Methods

This study uses the LCA methodology, following the ISO 14040/44:2006 standards (ISO 14040, 2006; ISO 14044, 2022), as outlined below.

3.1. Goal and scope

We apply nLCA tailored to the SSA context to evaluate the environmental impacts and nutrient adequacy of diets in three SSA countries under different socioeconomic conditions. With approximately 1.3 billion people, SSA is a socioeconomically diverse region, including countries with low, lower-middle, upper-middle, and high incomes (World Bank, 2025a). Despite rapid urbanization, the region continues to face an ongoing crisis characterized by high rates of food insecurity and undernutrition, extreme poverty, rising conflicts, climate-related shocks, and disease outbreaks (FAO et al., 2023). To determine local dietary patterns, we use the most recent nationally representative data on food consumption from thousands of households in Ethiopia, Ghana, and Nigeria. For Ethiopia and Nigeria, we use data from the Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA), conducted in 2018–2019 (World Bank, 2025b). For Ghana, we use data from the Ghana Living Standards Survey (GLSS7), conducted in 2016–2017 (Ghana Statistical Service, 2017). These surveys record household food consumption over the past seven days. In this study, households are categorized by country, location (rural and urban), and income quartile (Q1–Q4). Income estimates are based on aggregated adjusted annual consumption expenditures per capita expressed in local currencies.

The functional unit (FU) in our LCA is defined as the total quantity of food (in kilograms) consumed per adult equivalent (AE) per day. We estimate environmental impacts from agricultural production to

household entry. Fig. 1 describes the system boundary from farm to household entry including the following stages: (a) agricultural production, (b) transport of necessary inputs and raw materials, (c) processing, (d) packaging material, (e) distribution, (f) retail, (g) disposal at the retailer, and (h) transport to the household. We do not consider consumption at the household level and further downstream flows (e.g., disposal at the consumer), due to lack of data regarding consumption practices (i.e., cooking). We create waste scenarios to model disposal at the retail level considering waste of food and packaging material. However, food loss and waste at other supply chain stages are not quantified. Economic allocation is applied to estimate the share of impacts among co-products, including cut-offs to exclude irrelevant impacts from co-products of lower economic value.

3.2. Life cycle inventory (LCI)

3.2.1. Food consumption data

Food consumption at the household level is estimated using available LSMS conversion units to derive quantities for all food items expressed in kilograms. When no conversion factor is available, we estimate quantities on a weight-per-volume basis, using food densities from FAO/INFOODS (Charrondiere et al., 2012) or weight per piece/unit, or packaging data from the U.S. Department of Agriculture (USDA, 2025), or as specified by the manufacturer and other sources (Tsiboe, 2022; Zereyesus et al., 2016). Detailed information on assumptions for missing conversion factors can be found in Appendix A (S1–S5).

We convert household-level quantities into food consumption values in kilograms per AE per day. The AE scale is calculated by considering household size and composition, dividing each household member's specific sex-age energy requirements by the adult male (ages 19–50) reference value of 2550 kcal, and summing the AEs of all household members (Claro et al., 2010). The calculated food quantities for the three countries and subgroups are shown in Appendix A (S10–S12).

We apply decision rules for outlier removal based on total daily energy consumption, as outlined by Lee et al. (2020). For our analysis, we

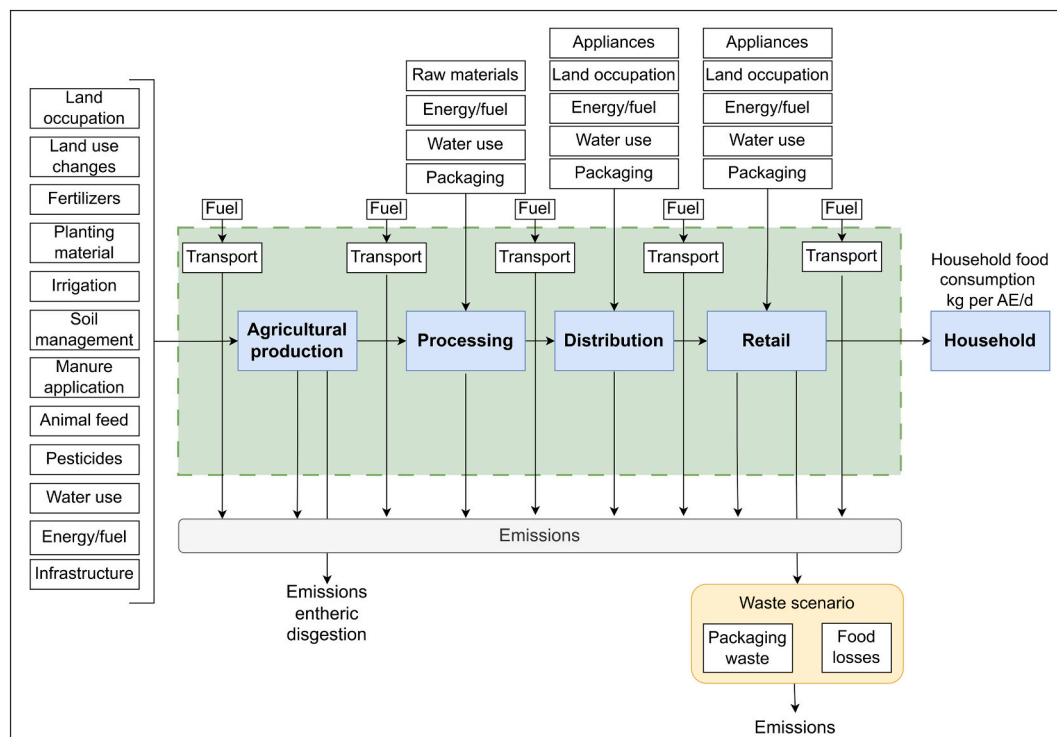


Fig. 1. System boundary from farm to household entry to estimate impacts of diets in SSA. The system represents one life cycle per food item, and the respective consumed quantities per functional unit (kilogram of food consumed per adult equivalent per day).

adopted the broader fixed range approach (500–5000 kcal/day) to handle extreme outliers in energy consumption by excluding values below 500 kcal and above 5000 kcal per AE per day. The final sample size (n) for the analysis is 10,004 for Ghana, 3783 for Nigeria, and 4149 for Ethiopia. Further details on data processing can be found in Appendix B (Table S1).

In addition to evaluating actually-observed diets, we develop a Healthy Diet (HD) standard for comparison, drawing on the FBDGs for Ghana (Ministry of Food and Agriculture, 2023). Taking into consideration serving size and amounts of servings per recommended food group, the HD contains 66 food items totalling 2456 kcal and adequacy for all relevant nutrients (see Appendix A, S17). This HD pattern is used to assess the environmental impacts of a shift from current diets to healthier diets in all three SSA countries. We chose the Ghana FBDGs because they provide more detailed quantitative recommendations than existing guidelines for the other countries. Using the same guidelines facilitates data pooling and comparisons across the three study countries, even though this approach cannot capture certain local peculiarities.

3.2.2. Development of LCIs for the SSA context

LCA modelling is conducted in SimaPro v. 9.6.0.1 (PRé Sustainability, 2025), based on specific data sources and methodological assumptions (Appendix B, Table S2). The background data on LCIs is sourced from the AgriFootprint 6 and Ecoinvent v3.9.1 databases (Blonk et al., 2022; Wernet et al., 2016). We estimate aggregated impact values per kilogram of various food items and beverages within the established system boundary (Fig. 1). Wherever possible, we utilise available inventories of African origin for several agricultural products and raw materials. When data for the African continent are unavailable, we often use global-level data, or data from other regions. Inventories are adjusted by modifying the use of natural resources (e.g., water, land use, land transformation), energy, and raw material markets to suit the SSA context.

We use the FAO trade mix 2021–2022 (FAOSTAT, 2025) to determine the origin of imported food items. Other food items are assumed to be “local”. Some food items consumed by households in SSA are not included in available LCIs. Therefore, we compiled information on processes from the literature, modelled in conjunction with LCI data available in SimaPro (energy use, water use, emissions, etc.). This applies to many traditional foods, locally processed foods, and also to processes at the food distribution and retail stages (Appendix B, Table S2).

More specifically, each LCA stage includes the following components:

- Agricultural production:** The impacts of agricultural production arise from various activities, including annual or perennial crops, animal husbandry, and fishing, among others. Emissions are calculated based on land use and land-use changes per hectare for specific crops in a country (Reinhard et al., 2017). Emissions also come from several agricultural inputs and processes as specified in Fig. 1 and Appendix B, Table S2. For livestock production, emissions from animal feed, enteric methane, and manure management are also considered.
- Transport of inputs and raw materials:** The transport of inputs and outputs across sub-stages is included, based on average travel distances for different modes of transport (road, rail, and sea). Based on studies of vehicle emissions in Ghana and Rwanda and transport regulations in Africa, we assume EURO3 emissions for road transport (Ayeter et al., 2021a, 2021b).
- Processing stage:** LCI includes the processing of raw materials, such as milling, oil extraction, refining, animal slaughtering, and fish processing (specifications are in Appendix B, Table S2).
- Packaging materials:** The production and transport of the most common food packaging materials are included (Appendix B,

Table S2), modelled according to the Product Environmental Footprint (PEF) Guidance (European Commission, 2018).

- Distribution:** Modelling is based on the PEF Guidance (European Commission, 2018), with adaptations made for SSA (see details in Appendix B, Table S2).
- Retail:** Retail activities are also based on the PEF Guidance (European Commission, 2018), with context-specific adjustments. Based on the Ghanaian retail sector (Meng et al., 2014; Zu et al., 2014), we assume a retail structure composed of 69.1% traditional open-air market outlets, 16.5% supermarket chains, and 14.4% street vending (see Appendix B, Table S2). We assume there is neither energy nor material consumption in street vending, but we do take into account the allocation of impacts. Food losses are considered based on FAO (2011).
- Disposal (retail):** We create LCI for waste scenarios to represent municipal solid waste management in SSA. Disposal is applied to food losses at the retail level, and the respective wasted packaging material. Currently, the municipal waste collection rate is approximately 44%, with waste directed to controlled landfills. The recycling rate stands at 4% of the collected waste. The remaining waste is typically disposed of in sidewalks, open fields, rivers, and drainage systems, often coupled with open burning (Adedara et al., 2023; Godfrey et al., 2019). For further details, see Appendix B, Table S2.
- Household transport:** Consumer transport for purchasing food items is estimated based on household transport expenditures in African cities (Olvera et al., 2007). We assume an average distance of 5 km, with transport shares allocated as follows: 1.2% for passenger cars (owned vehicles), 2.5% for motorized two-wheelers, 16.5% for van trips, 27.6% for regular buses, and 52.2% for walking.

3.3. Life cycle impact assessment

This study takes an nLCA approach. The nutritional assessment refers to food and nutrient availability at the household level, not to individual intakes. Environmental impact assessment is conducted at the midpoint level, encompassing the life cycle within the pre-established system boundaries from farm to household entry (Fig. 1).

3.3.1. Environmental impact categories

The environmental impact categories are assessed at the midpoint level using the ReCiPe 2016 characterisation method, which is representative of the global scale from the Hierarchist perspective (H), i.e., the most common policy principles relative to the time frame (Huijbregts et al., 2016). The impact categories assessed in this study are:

- Global warming, expressed in kg CO₂-eq of greenhouse gas emissions;
- Land use, in m²/year of annual cropland equivalents (m²a crop-eq) of land transformed or occupied per year;
- Water consumption (blue water), expressed in m³ of water consumed or extracted.

These categories are the most widely explored in the context of sustainable diets (Harrison et al., 2022), which enables us to compare our results with those from the literature, mostly referring to high-income countries. We express results for the actual dietary patterns observed. Environmental impacts per kg of food item are shown in Appendix B, Table S3.

3.3.2. Nutrition quality indicators

We characterize observed diets in terms of the nutrient adequacy ratio (NAR) for each nutrient, the mean adequacy ratio (MAR) across all relevant nutrients, and the household dietary diversity score (HDDS). These indicators are further explained in the following.

Based on the food consumption data, we calculate the availability of

21 macronutrients and micronutrients in each household. The nutrient content per 100 g of the edible portion is retrieved from the FAO/INFOODS food composition tables for West Africa (2019), and from other sources to complement data gaps (Vincent et al., 2020; USDA, 2025; Ethiopian Nutrition Institute, n.d.). Nutrient composition data for food items in each country are specified in Appendix A (S6–S9). Nutrient availability per AE per day is estimated for each household using nutrient-specific AE weights (Ali and Villa, 2022; Coates et al., 2017). These weights are calculated using age- and sex-specific proportions of the estimated average requirement (EAR) for an 18–30-year-old adult male, while considering household size and composition (Schneider and Herforth, 2020). The estimated daily consumption of a specific nutrient per AE ($ECae_i$) is obtained by multiplying food quantities (in kilograms) by the nutrient content (per 100 g of the edible portion) and dividing by household nutrient-specific AE weights.

NAR is calculated for each nutrient i by dividing $ECae_i$ by EAR_i for an adult male 18–30 years old (Institute of Medicine, 2006). The estimation of MAR includes NAR_i for a total of 21 nutrients, using Eq. (1) and Eq. (2) (van de Locht et al., 2024):

$$NAR_i = \min\left(\frac{ECae_i}{EAR_i}, 1\right) \quad (1)$$

$$MAR = \frac{1}{n} \sum_{i=1}^n NAR_i \quad (2)$$

HDDS measures dietary diversity and counts the number of different food groups consumed by the household (Swindale and Bilinsky, 2006; Kennedy et al., 2010; Fongar et al., 2018), using the following 12 food groups: (1) cereals, (2) roots and tubers, (3) vegetables, (4) fruits, (5) meat, poultry, offal, (6) eggs, (7) fish and seafood, (8) legumes, nuts and seeds, (9) milk and milk products, (10) fats and oils, (11) sugar and sweets, (12) miscellaneous. These food groups are only used to calculate HDDS. For the LCA analysis, food groups are further disaggregated to properly reflect their environmental impacts.

3.4. Statistical analysis

Statistical analyses are performed using Stata 16 (StataCorp LLC, 2019). We present environmental impacts and nutritional quality of the average diets observed, differentiating by country and in each country by rural and urban areas and four income quartiles. For all relevant indicators we show mean values, standard errors, and 95% confidence intervals. NAR for specific nutrients is presented as median values within the 25th to 75th percentile. Uncertainty analysis using Monte Carlo techniques was applied to the LCA results in SimaPro to address data variation, model correctness, and completeness, with 95% confidence intervals. Results of the LCA and uncertainty analysis per kg of food item are provided in Appendix A (S13).

To examine the relationship between the various environmental impact categories and nutritional quality indicators, we use Spearman's rank-order correlation coefficients. A normality check was applied (Shapiro–Wilk's test) to justify the use of nonparametric analysis for non-normally distributed data. We run the correlations for the pooled sample, including the observations from all three countries, and also separately for each country, with a coefficient significance level of 0.05.

Additionally, we compare current dietary patterns with a hypothetical Healthy Diet (HD) (see Appendix A, S17) to evaluate the environmental impact of shifting towards healthier diets. We compare the HD with the average observed diets in the three countries, as well as with the diets of lower- and higher-income quartiles, to explicitly examine potential sustainability tradeoffs associated with improved nutritional quality.

Furthermore, we use regression models to analyze the role of income growth and urbanization in more detail. More specifically, we want to examine whether income and household location in urban versus rural

areas are associated with changes in the environmental and nutritional impacts of diets. We estimate regression models of the following type:

$$Y_h = \alpha + \beta Inc_h + \gamma Urb_h + \delta C + \varepsilon_h \quad (3)$$

where Y_h is the particular outcome indicator of the diet consumed in household h . We estimate separate models for global warming, land use, and water impacts, as well as for MAR. Inc is the annual per capita income in household h , expressed in thousand international dollars using purchasing power parity exchange rates (World Bank, 2024). Urb is a dummy variable that takes a value of one if the household is located in an urban area, and zero if it is located in a rural area. As we run these models for the pooled sample, we also include country fixed effects, C . As the dependent variables are not normally distributed, we use log transformations on the left-hand side of Eq. (3). The estimation coefficients can therefore be interpreted as percentage changes.

4. Results

We summarize our key results in Box 1 with further details provided below.

4.1. Environmental impacts of diets

Table 1 shows the environmental impacts of diets on global warming, land use, and water consumption per AE/d, broken down by country, location (urban/rural), and income quartile (Q1–Q4). On average, the diets in Nigeria and Ghana have a higher impact on global warming (2.42 and 2.43 kg CO₂-eq per AE/d, respectively) than the diets in Ethiopia (1.78 kg CO₂-eq per AE/d). However, the diets in Ethiopia have nearly twice the impact on water consumption (0.28 m³ per AE/d) than the diets in the other two countries (0.16 and 0.18 m³ per AE/d). Land use impacts are fairly similar across countries, ranging from 3.13 m²a crop-eq in Ghana to 3.63 m²a crop-eq in Nigeria. The impacts increase from rural to urban, except for water use in urban Nigeria. Furthermore, the impacts increase quite sizeably with rising household incomes. In all three countries, the environmental footprints of diets are at least twice as high for households in the richest income quartile (Q4) than for households in the poorest quartile (Q1).

The differences in environmental impacts are influenced by the food quantities consumed, but the more important factor is dietary composition. Fig. 2 illustrates the contribution of each environmental impact by food group in each country in urban and rural areas. *Cereals and their products* account for 20–36% of the global warming impacts and for 27–55% of the water consumption (Fig. 2a, c).¹ *Meat and poultry products* account for 24% of the global warming impacts of diets in Nigeria and 13% in Ethiopia and Ghana (Fig. 2a). Meat and poultry play a larger role for land-use impacts, contributing 32% in Ghana, 51% in Nigeria, and 19% in Ethiopia (Fig. 2b), primarily due to beef consumption. We also observe important differences between rural and urban areas. While cereals play a larger relative role for the environmental impacts of diets in rural areas, in urban areas the role of meat products increases considerably. On average, urban households consume almost twice the quantity of ASF as rural households (Table S4, Fig. S2 in Appendix B).

Milk and dairy products also contribute significantly to land-use impacts in Ghana (26%) and Ethiopia (22%), mainly due to the

¹ The water consumption impact in Ethiopia is particularly large due to high consumption of cereals and cereal-derived beverages (malted beverages), some of which have local cultural values (Tadesse et al., 2020). Due to the lack of data on water footprints of cereal production in Ethiopia, we extrapolated data from South Africa, where some of the cereal production is irrigated (Dube et al., 2020). In Ethiopia, most of the cereal production is rainfed (Gebrehiwet and Pandey, 2025), which means lower yields but also lower blue water consumption. As a result, the water consumption impact of cereals as reported here may possibly be somewhat overestimated.

Box 1

Key messages.

- Environmental impacts of diets increase with income growth and urbanization.
- The main dietary contributors to these increasing environmental footprints are cereals, meat/poultry, milk/dairy, and beverages.
- Rural diets are starchy staple-based, but urbanization and higher incomes lead to dietary shifts and diversification.
- Nutrient deficiencies are widespread, especially with respect to several micronutrients.
- Tradeoffs exist between nutrition and environmental goals: higher nutrient adequacy is associated with higher environmental impacts.

Table 1

Environmental impact of diets in Ghana, Nigeria, and Ethiopia (per adult equivalent per day).

Country		Global warming (kgCO ₂ -eq)			Land use (m ² a crop-eq)			Water consumption (m ³)		
		Mean	Std. Err.	CI 95%	Mean	Std. Err.	CI 95%	Mean	Std. Err.	CI 95%
Ghana	Total	2.42	0.02	2.38–2.47	3.13	0.06	3.02–3.24	0.18	0.00	0.18–0.19
	Rural	2.23	0.03	2.18–2.28	2.35	0.05	2.26–2.45	0.17	0.00	0.16–0.18
	Urban	2.71	0.04	2.63–2.79	4.29	0.11	4.07–4.52	0.20	0.00	0.19–0.21
	Q1	1.67	0.05	1.58–1.77	1.73	0.11	1.51–19.5	0.13	0.01	0.12–0.15
	Q2	2.32	0.03	2.27–2.38	2.56	0.07	2.43–2.70	0.17	0.00	0.16–0.18
Nigeria	Q3	3.05	0.05	2.95–3.14	4.26	0.12	4.03–4.50	0.22	0.01	0.21–0.23
	Q4	3.16	0.05	3.06–3.26	5.23	0.13	4.97–5.50	0.27	0.01	0.25–0.28
	Total	2.43	0.02	2.38–2.47	3.63	0.05	3.52–3.72	0.16	0.00	0.16–0.16
	Rural	2.31	0.03	2.26–2.32	3.33	0.06	3.22–3.45	0.16	0.00	0.16–0.17
	Urban	2.65	0.04	2.58–2.73	4.19	0.09	4.01–4.37	0.15	0.00	0.15–0.16
Ethiopia	Q1	1.55	0.02	1.51–1.59	2.17	0.04	2.09–2.24	0.12	0.00	0.12–0.13
	Q2	2.11	0.03	2.06–2.17	3.01	0.06	2.89–3.13	0.15	0.00	0.14–0.15
	Q3	2.59	0.03	2.52–2.65	3.97	0.09	3.79–4.15	0.16	0.00	0.15–0.17
	Q4	3.45	0.06	3.34–3.56	5.33	0.14	5.05–5.60	0.21	0.01	0.20–0.22
	Total	1.78	0.02	1.74–1.82	3.28	0.07	3.15–3.42	0.27	0.01	0.26–0.28
	Rural	1.65	0.03	1.58–1.71	2.90	0.10	2.70–3.11	0.24	0.01	0.23–0.25
	Urban	1.91	0.03	1.86–1.96	3.65	0.09	3.48–3.82	0.30	0.01	0.28–0.32
	Q1	1.16	0.02	1.13–1.19	1.71	0.04	1.62–1.80	0.18	0.00	0.17–0.19
	Q2	1.69	0.02	1.64–1.74	3.04	0.08	2.88–3.20	0.27	0.01	0.25–0.29
	Q3	2.21	0.04	2.13–2.29	4.29	0.13	4.03–4.55	0.34	0.02	0.31–0.37
	Q4	3.06	0.11	2.84–3.28	6.71	0.39	5.94–7.48	0.41	0.03	0.36–0.46

Note: Q1–Q4 denotes the income quartiles, with Q1 representing the poorest and Q4 the richest 25% of households in each country.

consumption of evaporated and canned milk (in Ghana), as well as whole milk (in Ethiopia). Beverages play a significant role in water consumption impacts, which are particularly high in Ethiopia (averaging 35%), especially in urban areas (Fig. 2c). The top five beverages are non-alcoholic malted beverages, beer, tea, roasted coffee, and chocolate milk powder. In Ghana, *vegetables and their products* account for a substantial portion of water consumption impacts (36%), where tomato paste plays a significant role. More detailed results can be found in Appendix A (S14–S16).

4.2. Nutritional quality of diets

Generally, the diets in the three countries contain a large share of starchy staples, including cereals and starchy roots (e.g., cassava, yam). Purchased beverages, including alcoholic and non-alcoholic drinks, are also relevant, especially in urban diets (Appendix B, Table S4). Table 2 shows the nutritional quality results in terms of energy consumption, MAR, and HDDS per AE/d in each country, broken down by location (urban/rural) and income quartile (Q1–Q4). Overall, the HDDS in Ghana (8.4 food groups) and Nigeria (10.0 food groups) is higher than in Ethiopia (6.9 food groups). As one would expect, dietary diversity tends to increase with household income and residence in urban areas.

Even though Ethiopia's total food consumption by weight (0.87 kg/AE day) is lower than Ghana's (1.25 kg/AE/d) and Nigeria's (1.13 kg/AE/d), its average estimated energy consumption is 2959 kcal, which is higher than Ghana's (2,429 kcal) and only slightly lower than Nigeria's (3,025 kcal) (Table 2 and Appendix B, Table S4, Fig. S2). Diets in

Ethiopia are typically rich in cereals like teff, wheat, and barley, and in oils, which provide more energy per gram than starchy roots that are consumed more widely in Ghana and Nigeria. Energy consumption increases with household income and is generally higher in urban than rural areas (with the exception of Nigeria, where rural and urban energy consumption is similar). The energy levels reported here may appear high, which is due to the fact that our data reflect household food consumption per AE, which is higher than actual intakes of individual household members. Our results are broadly in line with the dietary energy supply reported by FAO (FAOSTAT, 2025).

MAR summarizes the mean NAR of all nutrients (Table 2). More detailed results on specific nutrient NARs are reported in Appendix B, Tables S5 and S6. Nutrient deficiencies are widespread, especially in the poorer income quartiles. Overall, Nigeria has the highest MAR (0.86), compared to Ghana (0.79) and Ethiopia (0.77). In all three countries, the most critical nutrients are (Appendix B, Table S5) vitamin E, riboflavin, calcium, and potassium, for which more than half of all households fail to meet the EARs. In Ethiopia, additional deficiencies at critical levels are observed for vitamins A, C, and B12, with 70–90% of all households failing to meet the EARs (Appendix B, Table S6).

4.3. Relationships between nutritional quality and sustainability

Table 3 shows the results of the Spearman's correlation analysis between nutritional quality and environmental indicators for the pooled sample. Within the nutritional quality indicators, we observe a moderate positive correlation between MAR and HDDS ($\rho = 0.4630$, $p < .001$),

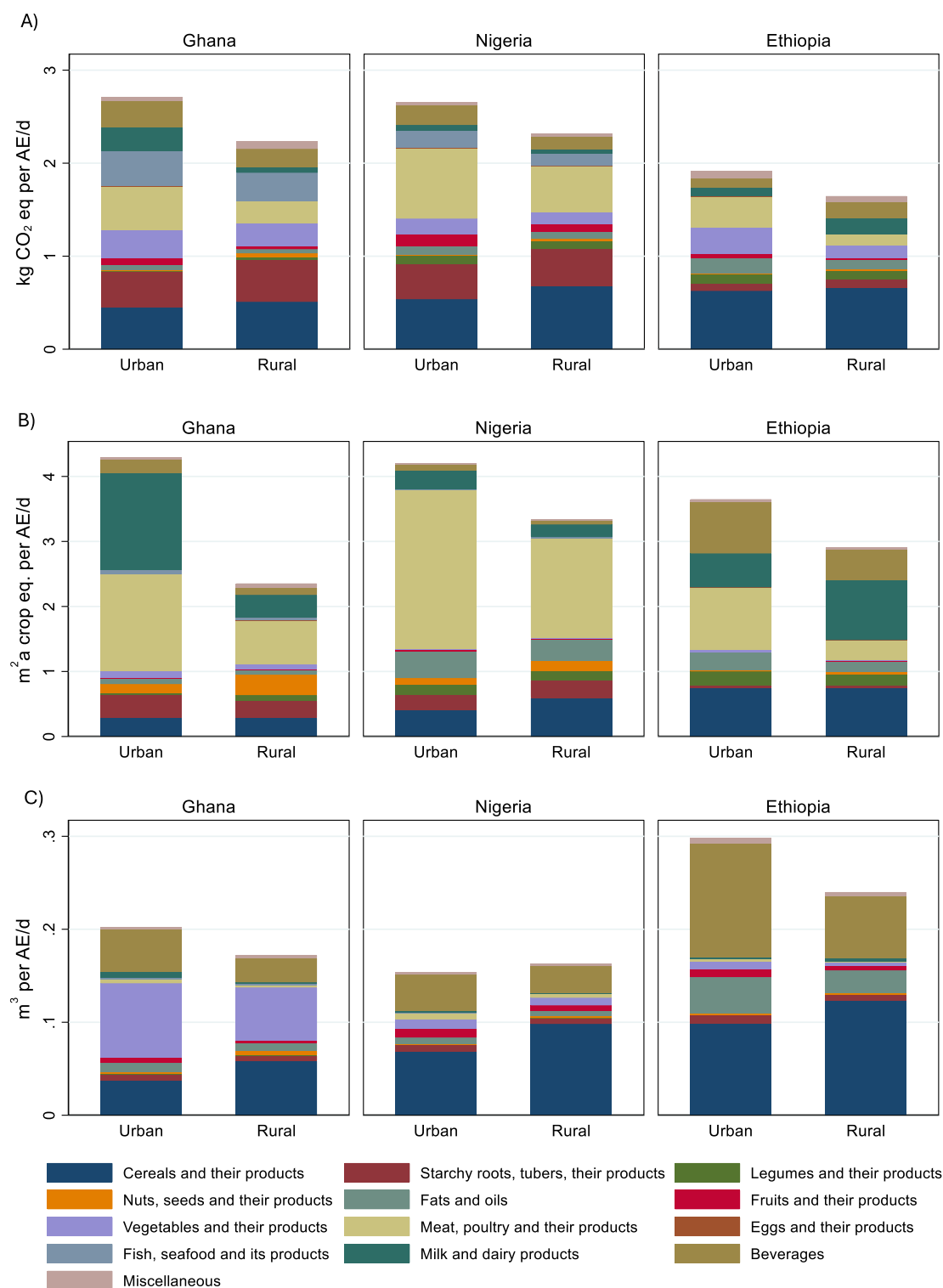


Fig. 2. Environmental impacts of diets in Ghana, Nigeria, and Ethiopia by food group, differentiating between rural and urban areas. A) global warming in kg CO₂-eq; B) land use in m²a crop-eq; C) water consumption in m³.

suggesting that higher levels of dietary diversity are associated with improved nutrient adequacy. Within the environmental indicators, we observe a strong positive correlation between global warming and land use ($\rho = 0.7402$, $p < .001$), and a moderate positive correlation between these two and water consumption ($\rho = 0.4977$ and 0.4659 , respectively, $p < .001$). This is expected, since the impact on water consumption derives from a different set of food items than the impact

on global warming and land use. The relationships between the nutritional and environmental indicators show a strong positive correlation between MAR and global warming ($\rho = 0.7402$, $p < .001$), and between MAR and land use ($\rho = 0.5734$, $p < .001$), as well as a moderate positive correlation between MAR and water consumption ($\rho = 0.4179$; $p < .001$). HDDS has a moderate positive correlation with global warming and land use, as well as a weak, yet significant, correlation

Table 2

Estimated household energy consumption, nutrient adequacy, and dietary diversity per adult equivalent per day, by country, location, and income quartile.

	Energy consumption (kcal per AE/d)				Mean adequacy ratio (MAR)				Household dietary diversity score (HDDS)			
	Mean	Std. Err.	CI 95%		Mean	Std. Err.	CI 95%		Mean	Std. Err.	CI 95%	
Ghana												
Total	2429.0	11.40	2406.7	2451.4	0.81	0.00	0.81	0.82	8.36	0.02	8.33	8.40
Rural	2399.0	14.56	2370.2	2427.3	0.81	0.00	0.80	0.81	8.14	0.02	8.10	8.19
Urban	2474.7	18.29	2438.8	2510.5	0.82	0.00	0.82	0.83	8.69	0.03	8.63	8.75
Q1	2013.8	18.23	1978.0	2049.5	0.73	0.00	0.73	0.74	7.78	0.03	7.73	7.84
Q2	2423.6	20.13	2383.7	2462.6	0.83	0.00	0.82	0.83	8.59	0.03	8.53	8.66
Q3	2767.9	22.85	2723.1	2812.7	0.88	0.00	0.87	0.88	8.95	0.04	8.88	9.03
Q4	2754.9	30.85	2694.4	2815.4	0.83	0.01	0.83	0.85	8.19	0.06	8.08	8.31
Nigeria												
Total	3025.1	16.4	2993.8	3058.0	0.86	0.00	0.85	0.86	10.04	0.03	9.99	10.10
Rural	3066.2	20.39	3026.6	3106.5	0.85	0.00	0.85	0.86	9.77	0.03	9.70	9.83
Urban	2944.9	27.21	2891.5	2998.3	0.87	0.00	0.86	0.87	10.59	0.04	10.51	10.68
Q1	2552.6	30.49	2492.6	2612.2	0.78	0.00	0.78	0.79	9.23	0.05	9.13	9.33
Q2	2951.5	31.85	2891.1	3016.1	0.84	0.00	0.84	0.85	9.98	0.05	9.88	10.08
Q3	3141.9	31.02	3081.1	3202.9	0.88	0.00	0.88	0.89	10.54	0.05	10.45	10.64
Q4	3455.3	30.50	3395.3	3514.9	0.92	0.00	0.91	0.92	10.41	0.05	10.31	10.52
Ethiopia												
Total	2959.0	16.8	2926.0	2992.1	0.77	0.00	0.77	0.78	6.88	0.03	6.82	6.94
Rural	2854.5	24.10	2807.3	2901.8	0.72	0.00	0.72	0.73	6.22	0.04	6.16	6.30
Urban	3060.7	23.34	3014.9	3106.5	0.82	0.00	0.81	0.82	6.88	0.04	7.43	7.60
Q1	2428.2	26.15	2376.9	2479.5	0.66	0.00	0.65	0.67	5.90	0.04	5.82	5.98
Q2	3060.1	29.38	3002.4	3117.7	0.79	0.00	0.78	0.80	6.90	0.04	6.81	6.98
Q3	3381.9	30.49	3322.1	3441.8	0.86	0.00	0.85	0.87	7.79	0.06	7.68	7.91
Q4	3533.2	44.17	3446.4	3619.9	0.89	0.01	0.88	0.90	8.11	0.10	7.91	8.31

Note: Q1–Q4 denotes the income quartiles, with Q1 representing the poorest and Q4 the richest 25% of households in each country.

Table 3

Spearman's correlation coefficients between nutrition and environmental indicators.

		MAR	HDDS	GW	LU	WC
MAR	Spearman's rho [†]	1.0000				
	Sig (2-tailed)					
HDDS	Spearman's rho	0.4630*	1.0000			
	Sig (2-tailed)	p < .001	.			
GW	Spearman's rho	0.7905*	0.4774*	1.0000		
	Sig (2-tailed)	p < .001	p < .001	.		
LU	Spearman's rho	0.5734*	0.4584*	0.7402*	1.0000	
	Sig (2-tailed)	p < .001	p < .001	p < .001	.	
WC	Spearman's rho	0.4179*	0.1680*	0.4977*	0.4659*	1.000
	Sig (2-tailed)	p < .001	p < .001	p < .001	p < .001	.

Note: Spearman's correlation coefficient rho (−1 to 1, 0 no correlation), $N = 17,943$. MAR: Mean adequacy ratio; HDDS: Household dietary diversity score; GW: Global warming; LU: Land use; WC: Water consumption. Asterisks (*) indicate statistical significance (two-tailed significance level, $p < .001$).

with water consumption. These patterns indicate that higher nutrient adequacy is associated with higher environmental impacts. This is also confirmed when running the correlation analysis in the three countries separately (Appendix B, Table S7).

To further elucidate the relationship between nutrition and environmental sustainability, we evaluate the environmental outcomes of shifting from current diets to a Healthy Diet (HD), as recommended by FBDGs. Fig. 3 compares the environmental impacts of currently observed diets and HD per AE per day. On average, the adoption of the HD would increase global warming impacts by 35–52%, land use by 29–39%, and water consumption by 5–44%. For low-income households (Q1), the shift to HD would lead to over-proportional increases in environmental impacts, as these households have the lowest baseline

food and nutrient consumption levels. In contrast, for households in the highest income quartile (Q4), adherence to the HD would result in only slight increases in global warming impacts, while reducing land use and water consumption. These richer households currently consume many highly processed foods and beverages, which are not part of the HD.

4.4. Role of income growth and urbanization

Fig. 4 displays the results of regressing MAR and environmental impact indicators on household income and urban location using the pooled sample and controlling for country fixed effects. A \$1000 increase in annual income is associated with only a 1.6% increase in MAR (coef.: 0.016, $p < .001$). At the same time, a \$1000 increase in income is associated with a 9.3% increase in global warming (coef.: 0.093, $p < .001$), a 12.8% increase in land use (coef.: 0.128, $p < .001$), and a 9.8% increase in water consumption (coef.: 0.098, $p < .001$). Regarding urbanization, urban households have a 2.2% higher MAR (coef.: 0.022, $p < .001$) and create 7.8% higher global warming (coef.: 0.078, $p < .001$), 27% higher land use (coef.: 0.273, $p < .001$), and 5.4% higher water consumption (coef.: 0.054, $p = .001$) impacts than rural households. These findings corroborate the descriptive results in Table 1 and Table 2.

Separate regression results for each country are shown in Appendix B (Fig. S3). They confirm the positive and significant associations between income, MAR, and all environmental impact indicators. For urban location, the findings are more nuanced. Urban diets have larger global warming and land use impacts than rural diets in Ghana and Nigeria, but not in Ethiopia. Urban diets have larger water consumption impacts than rural diets in Ghana and Ethiopia, whereas in Nigeria we observe the opposite. And, urban location is positively associated with MAR in Ethiopia, but not in Ghana and Nigeria. Note, however, that these regression estimates for urbanization hold income constant. In reality, urban households tend to be richer than rural households, and the environmental footprints of urban diets are larger than those of rural diets in all three countries, as shown in Table 1 and Fig. 2.

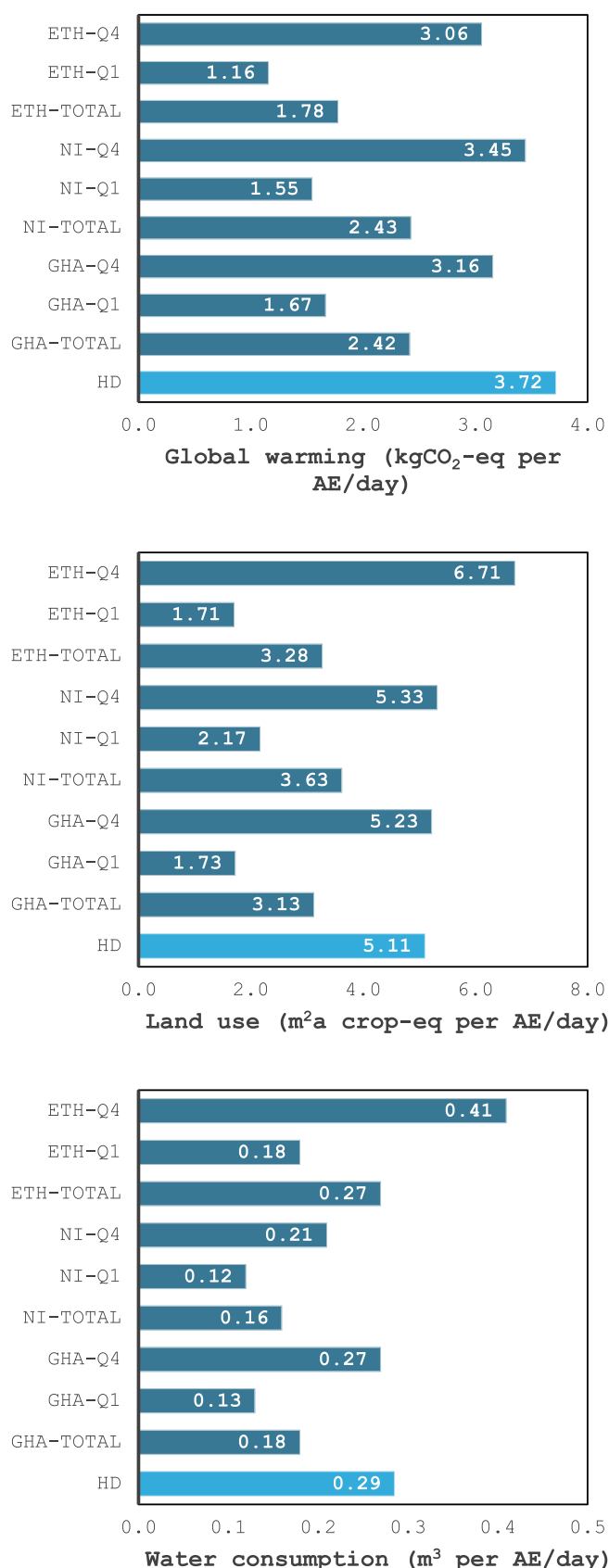


Fig. 3. Comparison of a Healthy Diet (HD) and the average diets of Ghana (GHA), Nigeria (NGA), and Ethiopia (ETH) with respect to global warming potential, land use, and water consumption, stratified by lower to higher income quartile (Q1 and Q4).

5. Discussion

5.1. Sustainability assessment of diets in SSA

This study uses context-sensitive LCA and nationally representative food consumption data from three countries in SSA. We present background and foreground life cycle inventory data using methodological LCA adaptations to simulate production systems and consumption patterns in local SSA contexts, which is a novel contribution to existing literature. Using this context-adapted model, we conduct a comprehensive LCA analysis of diets in SSA under various socioeconomic conditions, considering environmental impacts as well as nutrition performance indicators. Additionally, we evaluate the relationships between environmental impacts and nutritional outcomes to identify potential synergies and tradeoffs associated with dietary transitions. Our main findings suggest that socioeconomic factors, such as income levels and urbanization, significantly influence dietary patterns and associated nutritional benefits, while also increasing environmental impacts. Environmental impacts of diets and MAR are higher in urban than rural areas, and they tend to increase with rising household incomes. This means that – under current dietary patterns and food preferences – there are clear tradeoffs between human health and environmental objectives. Such tradeoffs may be avoided through more environmentally-friendly food choices, but this will require changes in people's behaviour and local food environments.

Using local FBDGs, we explicitly show that shifts towards recommended healthy diets would lead to larger environmental burdens, especially among the poorer population segments who currently still suffer from undernutrition. So far, FBDGs in most African countries do not consider environmental impacts.

The environmental impacts of diets vary by country and context, but they are generally lower in SSA than in high-income countries of Europe or North America. We provide an overview of the average environmental impacts of diets in Europe and the USA from a review of the existing literature in Appendix B, Table S8. In comparison, the diets in Ghana, Nigeria, and Ethiopia, as estimated here, cause much smaller environmental impacts, which is largely attributable to lower quantities of food consumed, and much lower ASF consumption. However, we also show that the diets in SSA are heterogeneous and that rising incomes and urbanization are associated with larger consumption of ASF (meat and dairy), more highly processed foods, and purchased beverages (coffee, tea, juices, soft drinks, alcoholic drinks). In fact, the richer urban population segments, especially those in the richest income quartile, have fairly Westernized dietary patterns with environmental footprints similar to those in high-income countries. We cannot compare our results with other findings for Africa, as related previous research with nLCA analysis for countries in SSA does not exist.

Apart from differences in dietary patterns, the environmental impacts of diets may also differ because of dissimilar food production systems and technologies, which influence the LCA output per kilogram of food product (Appendix B, Table S3). For example, 1 kg of rice produced locally under typical SSA conditions has larger environmental impacts (GHG emissions: 4.22 kg CO₂ eq; land use: 2.17 m²a crop-eq; water use: 0.09 m³) than rice imported from India, Thailand, or Vietnam (GHG emissions: 3.36 kg CO₂ eq; land use: 1.83 m² a crop-eq; water use: 0.01 m³), due to inferior technology and lower yields in SSA. Technological improvements that contribute to productivity gains in the African small farm sector can therefore also help reduce some of the tradeoffs between improvements in dietary quality and environmental impacts.

5.2. Limitations

This study has data and methodological limitations that should be considered when interpreting the results. First, we use data on food consumption at the household level that were captured through 7-day

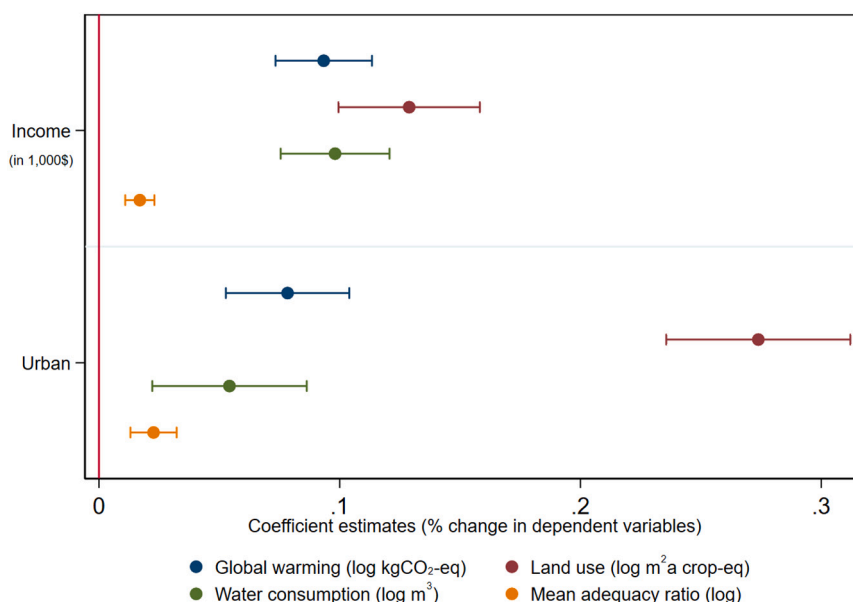


Fig. 4. Income and urbanization effects on environmental impacts (global warming, land use, and water consumption), and nutrient adequacy (mean adequacy ratio) of diets. Regression coefficients indicate percentage changes in the dependent variables when annual income increases by \$1000 or when households are located in urban vs. rural areas. Red reference line $x = 0$ indicates no association.

recalls. Such data come with inaccuracies in terms of recall and measurement error, non-standard unit data gaps, and different lists of food items across countries, which may potentially affect some of the comparisons.

Second, the diets calculated reflect food availability at the household level and not actual food intakes by individual household members. Although we account for household composition, we cannot determine the nutritional adequacy of specific household members. Individual-level 24-hour dietary recalls would be useful for more detailed nutritional analysis; however, such data are not available in existing nationally representative surveys for SSA.

Third, even though we clearly improve on local specificity of LCA in SSA, we build on several assumptions due to data gaps in the African context. These include (a) the extrapolation of data from a limited number of African countries to other countries in the region; (b) adapting available datasets from other regions to the African context; and (c) using available literature from fields other than LCA to model inexistent LCI. The LCA database we have created contains many food items commonly consumed in SSA, supported by a full list of literature references (Appendix B, Table S2), which we hope will also be useful for follow-up research. However, we emphasize the continuous need for data improvements, which may also require primary data collection in specific contexts.

Fourth, the Healthy Diet (HD) scenario is based on Ghanaian dietary guidelines and applied across multiple SSA countries. While this ensures comparability, it may not fully capture country-specific dietary recommendations and cultural consumption patterns in Ethiopia and Nigeria.

5.3. Recommendations for healthy and sustainable diets in SSA

This study offers insights into the environmental and nutritional aspects of diets in SSA settings, which may help develop context-specific recommendations for dietary improvements. Certain tradeoffs will be unavoidable, as enhancing overall nutrition in SSA will likely increase environmental impacts. However, the currently observed trajectories, where income increases and urbanization lead to Westernized dietary patterns that are harmful for both human health and the environment, should be modified. Food system policies and initiatives should focus on foods that are both nutritious and have low environmental impacts,

considering local availability and access across population groups in diverse socioeconomic contexts. This includes encouraging the consumption of legumes, fruits, and vegetables, with moderate increases in ASF among the poorer population segments, while discouraging less beneficial choices such as foods high in fat, sugar, and salt, as well as industrialized beverages.

Making healthy and sustainable diets more accessible and affordable will require multiple changes in food supply chains, food environments, and people's dietary preferences and actual food choices. Improved agricultural practices and technologies are needed, especially in the SSA small farm sector, to increase productivity and farm incomes while reducing resource use and environmentally harmful emissions. Further, efficiency gains in food processing and distribution are needed, especially with a view to perishable and nutritious food items. Food security policies should mainly target the most vulnerable low-income households in rural and urban areas to foster adequate nutrient intake and increase dietary diversity. For higher-income households, policies should aim to raise awareness about sustainability, food choices, and their impacts on human health and the environment. Ultimately, integrating nutrition, environmental sustainability, and inclusiveness into national and local development strategies and FBDGs will be crucial for promoting planetary health in SSA.

5.4. Policy and research implications

Based on our findings, we make a few concrete recommendations for policy and follow-up research.

- Ensuring sufficient access to nutritionally adequate diets for low-income populations in SSA needs to remain a primary policy objective, given existing nutritional inadequacies and high levels of food insecurity.
- Income growth and urbanization are associated with environmental impacts, partly driven by a Westernization of diets, highlighting the need for better nutrition education, awareness building, and other consumer-related interventions to incentivize healthier and more sustainable food choices.
- Suitable dietary patterns that align nutritional, environmental, and social goals need to be developed, considering local conditions and

food preferences. This will require multi-goal optimization work. Such optimized dietary patterns should then also be reflected in improved FBDGs. Our study can hopefully support such follow-up research.

- d) Improving the availability and quality of environmental impact data in SSA is a critical component of sustainable development. Given the limited coverage of LCA inventories in the region, coordinated efforts are needed to collect primary data, engage industry stakeholders in sharing environmental information, and strengthen communication between LCA data developers and practitioners. Such efforts would enhance data robustness and provide a more accurate representation of local environmental impacts.
- e) Dietary shifts alone are insufficient to achieve sustainable food systems. Complementary measures are required, including technological improvements in agricultural production to enhance resource-use efficiency, as well as interventions along supply chains to improve the accessibility and affordability of healthy foods and reduce food losses and waste.

Beyond the SSA context, this study contributes to ongoing global debates on sustainable diets by highlighting the relevance of context-specific sustainability assessments to identify potential tradeoffs and synergies between human health and the environment. In particular, our findings demonstrate that the observed tradeoffs vary across the different countries and dietary patterns, underscoring the need to move beyond one-size-fits-all dietary recommendations in the global context.

6. Conclusion

This study employs a context-sensitive LCA and nationally representative food consumption data from three countries to explore the relationships between nutrition and environmental sustainability in SSA. Our work contributes methodologically and empirically, in the sense that we adjust and improve LCA approaches and data to typical local conditions in SSA and evaluate the sustainability of local diets under heterogeneous socioeconomic conditions. While average diets in SSA have smaller environmental footprints than average diets in high-income countries, our findings suggest that improvements in nutritional quality are often associated with increases in environmental impacts. Currently, income growth and urbanization are driving the adoption of Western-style dietary patterns, which may be unhealthy for both human health and the environment. Smart policies should guide pathways towards more sustainable diets, which need to include technological improvements in agricultural production, food value chains, and food environments, as well as interventions to enhance consumer awareness and facilitate healthier and more sustainable food choices. Looking forward, our study identifies key priorities for policymaking and future research. Follow-up work is needed to optimize dietary patterns, better aligning the goals of healthfulness, low environmental impact, affordability, and cultural acceptability in local contexts. Furthermore, future research should analyze context-specific policies and entry points for implementing the needed dietary changes and other food system interventions.

CRediT authorship contribution statement

Juliana Minetto Gellert Paris: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ute Nöthlings:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Felix Ankomah Asante:** Writing – review & editing, Conceptualization. **Matin Qaim:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.spc.2026.04.007>.

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