RESEARCH

Open Access



Affordability of healthy diets is associated with increased food systems performance in Nigeria: state-level analysis

Daniel A. Mekonnen^{1*}, Olutayo Adeyemi², Rachel Gilbert³, Dare Akerele⁴, Thom Achterbosch¹ and Anna Herforth^{3,5}

*Correspondence: daniel.mekonnen@wur.nl

¹ Wageningen Economic Research, Wageningen University and Research, Pr. Beatrixlaan 582, 2595 BM Den Haag, The Netherlands ² Department of Human Nutrition and Dietetics, Faculty of Public Health, University of Ibadan, Ibadan, Nigeria ³ Friedman School of Nutrition Science and Policy, Tufts University, Boston, USA ⁴ Department of Agricultural Economics and Farm Management, Federal University of Agriculture, Abeokuta, Nigeria ⁵ Department of Global Health and Population, Harvard T. H. Chan School of Public Health, Harvard University, Boston, USA

Abstract

This study examines the relationships between healthy diets' affordability and food systems performance across Nigerian states. On a composite index (FSI) constructed from key food system components, states in the southern zones perform relatively better than those in the north, whereas a higher share of households who cannot afford a healthy diet was from northern states. Findings suggest the need for more focused attention on resilience building for improved food systems especially in northern Nigeria. Results also indicate cases where unaffordability of a healthy diet remains high in the face of comparatively lower cost and vice versa, highlighting the need for more efficient and equitable food supply systems. Findings of this study further suggest that achieving affordable healthy diets would require stepping up actions to improve, among others, access to basic services (such as good roads and electricity), increased presence of financial services (such as rural banks), greater access to information and communications services (mobile phone subscription rates and increased radio/television station coverage), facilitating more favorable and predictable business environment, and promoting women's empowerment.

Keywords: Cost of diet, Affordability, Food prices, Food systems, Nigeria

Introduction

Healthy diet is one of the basic needs for people to lead an active and healthy life. A healthy diet provides not only adequate calories but also adequate levels of essential nutrients and other food components that explain the link between food and health (Herforth et al. 2020). However, access to healthy diets by all people at all times has not been achieved by current food systems, due in part to affordability constraints (FAO et al. 2020; Bai et al. 2021). For example, despite improvements in household's spending toward meeting the cost of healthy diets (CoHD) in recent years, healthy diets are still unaffordable for lower income households in Nigeria. Based on data from 2018/19, a recent study shows that households in the lowest income (expenditure) quintile in Nigeria would have to increase food expenditures by 13% on average to be able to purchase the least-cost heathy diet, and by additional 43% to incorporate current preferences in



© The Author(s) 2023. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http:// creativeCommons.org/licenses/by/4.0/.

their choice of healthy foods (Mekonnen et al. 2021a). Furthermore, unaffordability of a healthy diet as measured by the least-cost diet as a share of food expenditures is higher in rural than urban areas; and correspondingly in the northern, relative to the southern zones, where the prevalence of poverty and inequality is also much higher (NBS 2020a). In 2019, the food expenditure share of the average household in Nigeria was about 56%, reaching over 60% in northern zones and rural areas (NBS, 2021a). Analysis of the same 2018/2019 NLSS data shows the food expenditure share of lower-income households (i.e., poorest 20%) was over 65%. This suggests that it would be challenging for poorer households to afford healthy diets without severely cutting back on important investments such as expenditures on education and health (Brinkman et al. 2010).

Many factors contribute to the cost and affordability of healthy diets either directly or indirectly (Bai et al. 2021). For instance, transport infrastructure links producers to input and output markets, reduces transport costs, contributes to agricultural productivity and improved incomes (FAO et al. 2020; Nakamura et al. 2019; Ali et al. 2015; Fan and Chan-Kang 2004), and facilitates employment opportunities (even though some social groups may lose their farmland to the construction of transport networks) (Khanani et al. 2021). Similarly, electricity contributes to food production as source of energy for irrigation, food processing, the use of information and communication technologies (ICT) and other innovations which facilitate food supply chains such as cold storage facilities that help reduce food losses and improve food supply (Candelise et al. 2021). Security, governance, and the strength of institutions are also critical components of the investment climate that facilitate entrepreneurship and innovations, which in turn influence the cost of transactions in food production, processing, marketing, distribution systems, and productivity (Audretsch et al. 2015; Venables 2015; Iimi 2008). Regardless of the channel, each component of food systems and food system drivers, when in place, can contribute to the creation of jobs, improvement of incomes and purchasing power (Hornberger et al. 2011; Aterido and Hallward-Driemeier 2010; Eifert et al. 2005), and increasing affordability of healthy diets (Herforth et al. 2020). Nonetheless, the business environment and food system components and drivers may differ across a country, and correspondingly their effect on affordability of healthy diets across states and socio-economic groups within a state may be different.

The National Bureau of Statistics' Annual Abstract of Statistics (2017) reveals differences among Nigerian states in terms of key food system indicators. For example, density of roads (length of roads in kilometres per square kilometre of land area) varied from 0.02 or less in Bayelsa, Yobe, and Sokoto to 0.15–0.20 in Anambra and Lagos states; and the share of households with access to electricity in 2016 varied from below 30% in Taraba, Jigawa, Zamfara, Yobe, and Bauchi to above 80% in Abia, Rivers, Edo, and Lagos, among others. Despite research to understand the relationship between household dietary diversity and nutrient adequacy and components of food systems (Mekonnen et al. 2021b), there is limited evidence linking affordability of healthy diets and food systems across Nigerian states. This study examines how the cost and affordability of healthy diets (CoAHD) are linked to differences in state-level food systems. The aim of this study is to contribute to policy conversations about where and for whom healthy diets are out of reach, and how to improve access through improved food systems. Better policies to address rising food prices and access to affordable, healthy diets can mitigate adverse impacts on household caloric availability and dietary diversity (Shittu et al. 2018), poverty (World Bank 2022) and social instability (Ismail 2021). Similarly, improved nutrition from healthier diets could have a multiplier effect across the Sustainable Development Goals (SDGs) (Development Initiatives 2017).

Data

Our main outcome of interest is the Affordability of a Healthy Diet, which compares the Cost of a Healthy Diet (CoHD) to an income standard. CoHD is defined as the cost per person, per day of the least expensive locally available foods that meet food-based dietary guidelines (FBDGs) (Herforth et al. 2022). We derive CoAHD from the 2018/19 Nigeria Living Standards Survey (NLSS). The NLSS contains a comprehensive and diverse set of socio-economic and demographic data collected between September 2018 and October 2019 by the National Bureau of Statistics of Nigeria (NBS), in collaboration with the World Bank (NBS 2020b). The initial sample targeted 22,200 households from 60 enumeration areas (EA) per state and the federal capital territory (FCT), Abuja. In each EA, 10 households were randomly selected for interview. The final sample covered 22,110 households, with response rate of above 98 percent nationally. The NLSS data file contains household weights which were calculated according to the selection probability of the EAs and the households, adjusting for nonresponse from each state (excluding Borno)¹. Apart from the state of Borno, the NLSS sample is representative at the state, zonal and national levels (NBS 2020c). To maintain representativeness of the sample, we apply the household weights in the analysis.

The food consumption module asked respondents about up to 111 different food and beverage items consumed in the household in the 7 days preceding the survey. The community survey includes information on retail prices in each EA. In total, market prices were collected from 682 urban and 1531 rural markets (N=2,213). However, since data were collected throughout the year, these prices need to be adjusted for spatial and temporal differences for comparability. NBS provides both spatial and temporal price deflators using a Paasche price index for each state and month. We apply these deflators before calculating median state-level prices for each food item. Further, the NLSS data file contains total household food expenditures, including by food group. We calculate daily food consumption expenditures per adult female equivalent (AFE). The AFE allows for a division of the household consumption to an individual household members' consumption as a proportion of energy requirements of an adult, non-pregnant, non-lactating woman. Active adult women are used as a reference as the Cost of a Healthy Diet metric is based on quantified food-based dietary guidelines with calorie targets of 2330, the median energy requirement for adult non-pregnant, non-lactating woman (2330 cal) (Bai et al 2022). That is, the least-cost diets to meet energy and nutrient requirements for people in this reference group are approximately the median level of least costs for all sex-age groups over the entire life cycle (Bai et al 2022).

¹ Due to security challenges during the survey, the nonresponse from the state of Borno was much higher, and hence the sample from Borno state is "considered non-representative and not comparable to other states" (NBS, 2020b. P.3). Hence, in this study we exclude Borno state from the analysis.

Data on food system indicators were obtained from various publications by the Nigeria National Bureau of Statistics as well as from other sources. These indicators were compiled at the state level for the Nigerian sub-national Food Systems Dashboard (see Appendix Table 4).

Method of analysis

Food system index (FSI)

A "food system" is a complex concept that embraces all elements—environment, people, inputs, processes, infrastructure, institutions, etc.—and activities that relate to the production, processing, distribution, preparation, and consumption of food and the outputs of these activities, including socio-economic and environmental outcomes (HLPE 2017). Since each element of the food system may have a bearing on the CoAHD either directly or indirectly, isolating the effect of any individual food system element is empirically challenging. Aggregating various elements into component indices and an aggregate index permits a ranking of states according to their relative performance in food system component scores and a composite food system index, respectively. Such information may help both federal and state governments to prioritize investments and assess the policy and institutional support needed to improve affordability of healthy diets, not-withstanding the common limitations of aggregate indicators (IFPRI et al. 2016).

Building on the "structure-conduct-performance" (SCP) framework (Bain 1959), an analytical tool to assess the influence of market and institutional drivers for decisionmaking on product and process innovations, van Berkum and Ruben (2021) proposed a food system index (FSI). The SCP framework comprises three interrelated aspects: (1) structural factors that drive food systems (population and urbanization, economic growth, weather and climate, and technology and infrastructure); (2) food systems components that reflect activities of food system stakeholders (production, markets and trade, consumption, and governance); and (3) food system outcomes including the likely trade-offs between them (diets and nutrition, environmental effects, inclusive livelihoods, equity and distribution). Since structural drivers are generally enablers and are subject to long-term change, their influence is largely reflected in the behavior of food system components, circumventing the need to include structural drivers in the proposed FSI (van Berkum and Ruben 2021). We adopt this approach to examine potential relationships between state-level food systems and the cost and affordability of healthy diets at the state level in Nigeria.

We developed a state-level FSI that relies mainly on food system components and food system outcomes. As the original FSI was designed for cross-country analysis, it has been adapted in a way that would reflect the state-level context in Nigeria. Indicators for this study (see Appendix Table 4) are chosen following van Berkum and Ruben (2021), and based on data availability across states in Nigeria including indicators compiled for the Nigeria Food Systems Dashboard (see Appendix Table 4). The select food system components include:

• *Food Production*: aim is to capture food supply (availability) through local production. Two proxy indicators include the average size of agricultural land owned by households that have agricultural land and the average cereal yield in the state. Growth in farm size may enable increases in agricultural production and increased cereal yield may increase food available for trade beyond local consumption (Masters et al. 2013).

- *Food Markets and Trade*: aim is to measure both physical and economic access to food, proxied by the Consumer Price Index (CPI) and road networks (road density) in the state. Road infrastructure reflects the ease and costs of mobility of people, goods and services, and is key for ensuring market access and efficient supply chains which have bearing on food availability. The CPI reflects economic access to food because food budgets are determined by the price of food but also of non-food goods and services (Meijer et al. 2018; Bai et al 2021).
- *Food Consumption:* aim is to measure food accessibility across socio-economic groups in the state, proxied by the mean per-capita expenditures, income inequality (Gini-index), and the percent of population below the national poverty line. Both income (purchasing power) and income distribution in the state contribute to food accessibility. Income inequality can be both a driver and a consequence of the food system. As a driver, income inequality can play into food production systems, the food environment and individual factors that influence access to food. As a consequence, inequality influences disproportionate spread of the burden of malnutrition and food insecurity (HLPE 2017; FAO et al. 2020).
- *Food Governance*²: aim is to capture how the regulatory environment in Nigeria is conducive to business operations through introduction of more business friendly regulations (laws) and stiffer property rights protections, among other important variables that can affect business performance within the food systems. The friendlier the business environment is in a given state within the country, the more attractive it is for private investments on business that can enhance food supply and accessibility which is a critical accelerator of economic growth and development. Ease of doing business is a quantitative indicator for defining the business friendliness of an economy. The role of governance in the day-to-day operations of small and medium-size domestic businesses is a fundamental focus of the ease of doing business (Ndukwe and Allison 2021). Widely used indicators that reflect ease of doing business include: rules and regulations for starting and operating mainly SME-type of enterprises, security of property, corruption (bribery) and legal frameworks for contract enforcement that are critical for enterprises in the food value chain (van Berkum and Ruben 2021)³. Select indicators for this study include the number of small and medium enterprises (SME) per 100 people, and the share of total cases of crimes reported in the state over the country total.

² Taking into account the complexities around conceptualizing and measuring food systems governance, Fanzo et al (2021) defined governance for positive food system transformation as "the mode of interaction among the public sector, private sector, civil society, and consumers to identify, implement, resource, and monitor solutions for achieving healthy, sustainable, resilient, just, and equitable food systems without leaving anyone behind" and proposed four indicator domains including shared vision, strategic planning and policies, effective implementation, and accountability (p.8). This was further refined by Schneider et al (2023) that proposed 10 indicators to capture food system governance across three dimensions including shared vision and strategic planning, effective implementation, and accountability. However, data on those indicators are not available at sub-national level in Nigeria.

³ Despite its coverage of 10 topics that may be better proxy for regulatory environment conducive to business operation, the World Bank's "ease of doing business index" was not used in this study as the indicator has been discontinued by the World Bank due to "data irregularities" and other "ethical matters." https://www.worldbank.org/en/news/statement/ 2021/09/16/world-bank-group-to-discontinue-doing-business-report.

• *Climate and Environmental Resilience*: aim is to capture resilience capacity of food production to climate and environmental factors. Select indicators include Herfindahl index (a measure of crop species richness per unit of land in production systems), ranging from 0 (complete diversification) to 1 (complete specialization) (Biswas 2016); the average tree/forest coverage, the average annual precipitation, and the average soil organic carbon stock in the state. Higher crop species richness and diversity are associated with several positive outcomes for production (e.g., yield stability, reduced pest and disease outbreaks, higher pollinator diversity) and the environment (e.g., higher insect and bird richness and abundance, higher soil biodiversity). Herfindahl index together with the above environmental factors capture the resilience capacity of food production in the state (Zomer et al. 2016; FAO 2017).

In what follows, we describe how we construct state-level FSI in Nigeria following van Berkum and Ruben (2021). First, we normalize attribute values so that indicators would be in the same scale and thus have the same importance (Han et al. 2012). For example, each dimension (*d*) of food system comprises between 2 and 4 indicators, and scores (S_i^d) for each indicator *x* in dimension (*d*) are scaled from 0 to 100, where 100 = the highest score, according to the following formula:

$$S_{xi,j}^{d} = \left(\frac{x_{i,j}^{d} - x_{i,\min}^{d}}{x_{i,\max}^{d} - x_{i,\min}^{d}}\right) * 100$$
(1a)

or,

$$S_{xi,j}^{d} = \left(\frac{x_{i,j}^{d} - x_{i,max}^{d}}{x_{i,max}^{d} - x_{i,min}^{d}}\right) * 100$$
(1b)

where $x_{i,j}^d$ is the value of indicator x in dimension d of the j' th state, $x_{i,\max}^d$ and $x_{i,\min}^d$ respectively, are the maximum and minimum values of that indicator across states. Indicators for which a high value implies desired outcomes are normalized as specified in Eq. 1a; whereas indicators for which a high value implies an unfavorable situation are normalized as specified in Eq. 1b. This is common practice when constructing composite indices in similar applications such as the Global Food Security Index (EIU 2019). The normalized value using Eq. 1b is then transformed into a positive number to make it directly comparable with values normalized using Eq. 1a. Examples of indicators for which a high value implies an unfavorable situation to affordability of food include the incidence of poverty, income inequality, incidence of crimes, and high inflation.

Second, we compute the score for each dimension d based on the numbers of indicators x in the dimension as follows:

$$S_{ij}^d = \sum_{1}^{n_d} \left(\frac{S_{xij}^d}{n_d} \right) \tag{2}$$

where $S_{i,j}^d$ is the score/value for dimension d, and n_d is the total number of indicators in the d th dimension. The FSI for state j is calculated as the unweighted sum of the average scores from d dimensions, which can be described as:

 Table 1
 Composition of the Healthy Diet Basket.
 Source: Herforth et al. 2022

Food Group	Number of food items selected	Energy content (kcal)	Typical weights of example foods (g)
Starchy Staples	2	1,160	322 g dry rice
Vegetables	3	110	270–400 g
Fruits	2	160	230–300 g
Animal-source Foods	2	300	210 g egg
Legumes, Nuts & Seeds	1	300	85 g dry bean
Oils & Fats	1	300	34 g oil
Total	11	2,330	

$$\mathrm{FSI}_{j} = \sum_{1}^{n} \left(\frac{S_{i,j}^{d}}{n} \right)$$

(3)

where n is the number of dimensions.

. .

The cost of a healthy diet (CoHD) calculation

The CoHD analysis of this study builds on a previous work in Nigeria by Mekonnen et al (2021a). First, this study further disaggregates the previous analysis to examine statelevel diet costs and affordability rather than national and zonal estimates. Second, due to lack of a quantified food-based dietary guideline (FBDG) for Nigeria, Mekonnen et al. (2021a) used Benin's FBDG. However, for the purpose of comparability across countries, this study uses the Food Prices for Nutrition global reference diet, the Healthy Diet Basket (HDB) (Herforth et al. 2022). The HDB is a globally relevant dietary standard which reflects the common elements of most national food-based dietary guidelines (FBDGs), which are designed to meet nutrient needs and prevent chronic disease. The specific number of items and food groups used in the HDB are based on median recommendations across ten quantified national guidelines. The CoHD based on the HDB allows substitution among locally available items at each time and place, while maintaining energy balance across and within food groups for a total of 2330 cal per person per day (Table 1).

Once the CoHD is calculated, affordability can be evaluated with respect to incomes or household expenditures. In this study, we evaluate affordability of healthy diet with respect to food expenditures per AFE. We describe affordability in terms of: (1) the CoHD as percent of food expenditures per AFE; and (2) the prevalence of households that cannot afford the CoHD, estimated as the share of households with food expenditures per AFE below the CoHD.

Assessment of relationships between food system performance and cost and affordability of healthy diet

Relationships between the CoAHD and the performance of state-level food systems were examined using non-parametric (kernel) regressions. Based on median values of FSI and cost and affordability, states were then classified into one of four quadrants for both the comparison between costs and food systems performance and that between affordability and food systems performance.

Although structural drivers were not included in the FSI calculation because their influence is understood to be reflected in the behavior of food system components, it was considered useful to see potential links between some indicators of structural drivers (for which state-level data is available) and the CoAHD. This is because data used in this study to construct the FSI were mostly cross-sectional, and hence the resulting FSI may not sufficiently capture the influence of structural drivers on the CoAHD. Thus, we assess bivariate relationships between select food system drivers and the CoAHD using non-parametric (kernel) regression. We further check these relationships with ordinary least squares regression, taking into account population density and internally generated revenue per capita of the state.

Results

We begin by presenting food system component scores across geopolitical zones, followed by the average food system index by geopolitical zones and states. We then present the CoAHD and their relationships with state-level food systems (index).

The food system index

Among the five dimensions selected for the calculation of FSI, there appears to be the most variation in the climate and environmental resilience, food production, and food markets and trade sub-components across states (Appendix Table 5) and geopolitical zones in Nigeria (Fig. 1). Average scores for the three dimensions ranged between 15 and 65, and the southern zones appear to perform better than those in the north. This performance of southern zones was also reflected in the aggregate food system index, where the average index for each of the southern zones was above the median (i.e., above median score of 45) while the corresponding figure for North East and North West zones was below the 25th percentile (Fig. 2a). With the average food system index of 30.3 and 56, respectively, Katsina and Oyo states took bottom and top places in the food system performance ranking (Fig. 2b). Other states that ranked higher than the 75th percentile include Ekiti, Edo, and Ebonyi, Osun, Plateau, Kaduna and Rivers. On the other hand, besides Katsina, the food system index for Adamawa, Sokoto, Yobe, Abuja, Zamfara, Kebbi, Jigawa, and Niger was below the 25th percentile.

The variations in food system index and its subcomponents highlight that food systems are not the same across zones and states in Nigeria. Even some states with similar overall food system index have very different scores across five food systems dimensions, depending on the performance of each of the five dimensions that make up the index (see Appendix Table 5). While several studies emphasize that important variations likely exist in subnational food systems (e.g., Marshall et al. 2021), there appears to be very few empirical studies of such variations. Thus, our study contributes to addressing a key gap in the literature.

Due to lack of data, indicators used in this study may not sufficiently capture some dimensions of the food system. This needs to be addressed in future studies as more data becomes available. However, our findings point toward the need for more focused attention on resilience building for improved food systems in northern Nigeria, especially in North East and North West zones. Naturally, there are zonal peculiarities between northern and southern Nigeria in terms of comparative and



Fig. 1 Performance of geopolitical zones by Food System Index (FSI) dimensions



Fig. 2 Average FSI scores across geopolitical zones and states

competitive advantage in relation to food production, trade and markets as well as climate and environmental resilience which may impact on the overall food system index rating. For instance, the northern zones have comparative advantage in the production of many crops, while the south has trade advantage, including seaports which facilitate easy access to raw materials and global supply chain distribution of finished food products. In addition, the relatively high rates of poverty and crises/insurgences in the north (Jaiyeola and Choga 2020; International Crisis Group 2020) may combine with elevated climate/environmental challenges such as drought, aridity, desertification (Federal Ministry of Environment 2021; Olagunju et al. 2021), among others, to weaken food systems resilience in the northern zones, most especially northeast and

	Mean	95% Cor Interval	nfidence	Min	Max
Cost of a healthy diet in 2018/19 Naira (\\	235	221	250	138 (Taraba)	308 (lmo)
Cost of a healthy diet as % of food expenditures	96	86	106	50 (Lagos	179 (Ebonyi)
% of households with per capita food expendi- tures below the cost of a healthy diet	35	25	37	5 (Lagos)	85 (Ebonyi)

Table 2 The mean Cost of a Healthy Diet and affordability (per adult female equivale

northwest. Issues of flood and erosion are also major environmental factors affecting food systems resilience in southern Nigeria (Akande et al. 2017; Echendu 2020).

Moreover, the highest food system index score (56) for the best performing state in the country (Oyo State) is still barely above average, reflecting a somewhat weak and fragile status of the Nigeria's food systems in general. Even though the food system index appears to rank most southern states higher than states in the north, it should be noted that the index is a relative measure, meaning that in our study, weak states were compared with weaker states. Hence, targeted action toward improving the various food systems components even among the seemingly better performing states should be pursued to prevent a down spiral food systems performance in states across Nigeria.

The cost and affordability of a healthy diet

Recall that the Healthy Diet Basket comprises 11 least-cost food items drawn from 6 food groups described in Table 1. Cassava roots, gari, and sorghum were the most common least-cost starchy staples across the states; groundnuts and soya beans were the most common least-cost legumes/nuts/seeds; and smoked fish and local cheese (wara) were the most common least-cost animal source foods. It is worth noting that least-cost food items may not always be the most preferred (Mekonnen et al. 2021a). For example, rice, wheat products, yam, millet, meat, and beans were rarely included in least-cost diets, with few exceptions (e.g., beans in Yobe, bush meat in Bayelsa, canned beef in Lagos and Zamfara).

The least-cost healthy diet cost 235 Naira per person per day in 2018/19 currency (Table 2). On average, this amounts to 96% of the daily food expenditures nationally. Here, affordability is evaluated with respect to the household expenditures on food. When affordability is considered in terms of the share of households whose food expenditures fell below the CoHD, results (national level) suggest that about 35% of households in the country cannot afford a healthy diet. The healthy diet was the least and most affordable in Ebonyi and Lagos states, respectively, with corresponding shares of households failing to meet the CoHD being 85% and 5% (Fig. 3).

Figures 3 and 4, respectively, describe the CoAHD for each state in Nigeria. The figures indicate that unaffordability of a healthy diet is not necessarily more prevalent among states where the cost is relatively the highest. For example, among nine states where the CoHD was above the 75th percentile, it was only three of them (Ebonyi, Abia, Imo) that belonged to the group of states with the relatively highest share of households who cannot afford a healthy diet (Figs. 3 and 4). On the other hand, among nine states where the CoHD was at or below the 25th percentile, Benue state



Fig. 3 Cost of a Healthy Diet across Nigerian states



Fig. 4 Percent of households with food expenditures below the Cost of a Healthy Diet

has the smallest share of households who cannot afford it (i.e., the share is below 16% or below the 25th percentile). These findings highlight that affordability is a function of both food prices and income and reveal the need to focus on food access in terms of reducing cost of healthy diets while also reducing poverty.

Correlations between cost and affordability of a healthy diet and food systems performance

In the preceding sections, we have analyzed the CoAHD in isolation of food systems performance. In this section, we bring them together and examine the relationships between the CoAHD and the performance of state-level food systems using non-parametric (kernel) regressions. According to Fig. 5, there appears to be a positive relationship between food system index (FSI) and the CoHD. The median values of the cost of healthy diet and FSI were used to plot the performance of the states in "quartiles" (matrix of FSI and CoHD). Hence, with respect to median values, quartiles Q1, Q2, Q3 and Q4, respectively, indicate higher cost and higher FSI, higher cost and lower FSI, lower cost and lower FSI, and lower cost and higher FSI. The states in quartile Q1 (higher cost and higher FSI) are all from the southern zones; and the states in quartile Q3 (lower cost and lower FSI) are from the northern zones with the exception of Lagos state. Similarly, the states in quartile Q4 (lower cost and higher FSI) are from the northern zones with the exception of Ekiti and Rivers state (from the South). In general, states in the south appear to be characterized by both higher cost and higher FSI. However, as noted above, higher cost may not necessarily mean less affordability or vice-versa, and this appears to be evident in Fig. 6. For example, even though the CoHD in most of the northern states was lower than the median (Fig. 6), two-thirds of the states that reported a higher share (above the median) of households who cannot afford the healthy diet were northern states (Fig. 6). According to Fig. 6, out of ten states in quadrant 4 (higher FSI and lower share of households who cannot afford a healthy diet), only two of them (Plateau and Benue) are from the north.

In states where diet costs and unaffordability are contemporaneously higher (largely in south-east zones), it means that cost is a much more serious challenge to affordability in the zone as opposed to those in the north where cost is relatively lower but



Fig. 5 The relationship between cost of healthy diet and food system index



Fig. 6 The relationship between affordability of healthy diet (percent of households with food expenditures below the cost of a healthy diet) and food system index

unaffordability is higher. Hence, efforts should be made to rigorously address the key drivers of high food costs and raise income especially for poor households in the South-East zone. Even in South-south zone where unaffordability seems relatively low in the face of high cost of healthy diets (compared to south-east zone), efforts should be geared toward taming cost/price escalation. Otherwise, growth in food costs may further outweigh income such that affordability for some of the households which ostensibly may seem better-off at the moment could decline, with states in the zone likely to become worse-off (or rank lower) in future in affordability ratings. More radical income-related interventions are needed to overcome affordability challenge for households in northern states such as Sokoto, Jigawa (North West), Adamawa, Gombe (North-East), and Niger (North Central) where high unaffordability still prevails despite the comparatively lower cost of healthy diets in the states.

In general, Fig. 6 appears to suggest a negative relationship between food system index (FSI) and the share of households with expenditures below the CoHD. However, the correlation does not seem too strong.

Regarding bivariate relationships between select food system drivers and the CoAHD, there appears to be a negative relationship between unaffordability of a healthy diet (the share of households with expenditures below the CoHD) and state-level food system drivers (see Annex Figs. 7, 8, 9, 10, 11, 12, 13 and 14 (right panel). That is, the better the food system drivers, the lower the unaffordability of a healthy diet. The selected state-level indicators include: revenue (per capita) generated within a state, share of households with access to electricity, rate of mobile phone subscription, number of radio and television stations per one million people, total employment in microenterprises as share of the population, the number of deposit banks per million people, stage of urbanization (proxied by average nightlight intensity), and gender parity in secondary

	Cost of healthy diet	Fraction of households with food expenditures below the cost of healthy diet	Cost of healthy diet	Fraction of households with food expenditures below the cost of healthy diet
Internally generated revenue per capita, 2016 (log)	1.622	- 0.129***	11.955	- 0.11***
	(8.151)	(0.039)	(8.127)	(0.035)
% households with access to electricity 2019	0.56	- 0.006***	1.319***	- 0.002
	(0.362)	(0.002)	(0.43)	(0.002)
% households with mobile phone sub- scription 2019	0.009	- 0.003**	- 0.027	- 0.001
	(0.183)	(0.001)	(0.323)	(0.001)
No. of radio &Tv stations per million people, 2016	- 0.087	- 0.01**	0.205	- 0.008**
	(0.731)	(0.004)	(0.903)	(0.004)
Employment in microenterprises as share of total pop	0.252	- 0.094***	7.988	- 0.077
	(6.154)	(0.03)	(11.76)	(0.05)
Number of deposit banks per million people, 2016 (log)	- 1.111	- 0.171***	27.694	- 0.009
	(11.523)	(0.056)	(20.047)	(0.09)
Average nightlight intensity (log)	3.47	- 0.134***	22.345**	- 0.023
	(8.204)	(0.039)	(10.412)	(0.048)
Gender parity in secondary school net attendance ratio	71.564*	- 0.359	107.72**	- 0.063
	(41.858)	(0.231)	(47.316)	(0.221)

 Table 3
 Correlation of cost and affordability of a healthy diet and food system drivers (OLS estimations)

Estimated coefficients come from separate regressions. Control variables were state-level population density (Total population per square km of land of the state) in Columns 2 & 3, and internally generated revenue per capita of the state in Columns 4 & 5. Standard errors in parenthesis

*** *p* < 0.01, ** *p* < 0.05, * *p* < 0.1

school net attendance ratio (where higher value indicates a gender disparity in favor of women). The correlations remain statistically significant after controlling for state-level population density (total population per square kilometer of land area) (Table 3). Findings established that affordability of healthy diets and more functioning food systems can be substantially promoted/achieved with concerted efforts (by governments at all levels, the private sectors and other key food systems players working together) to radically improve access to basic services, financial services, information and communications services, promote favorable business climate and deliberate actions toward women empowerment (though education), among others. However, the relationship between each of these indicators and CoHD tends to be positive, monotonic but nonlinear (i.e., both the cost of healthy diet and food system indicators increase concurrently, but not at the same rate) (Annex Figs. 7, 8, 9, 10, 11, 12, 13 and 14, left panel), even though the correlation was statistically significant only for one indicator—gender parity ratio (Table 3). In general, the graphs indicate that even though the CoHD appears to increase with food system drivers, unaffordability appeared to decline much more with food system drivers. It means that increasing incomes of agricultural households (likely meaning higher prices) in the context of increased food systems performance does not appear to hurt purchasing power of net buyers of food. That is, both higher incomes and better livelihoods can be achieved for food producers while making food more affordable with improved food systems.

The co-movement between access to electricity and diet cost may be related to the somewhat high cost of accessing electricity in the country.⁴ When there is grid electricity, the reality is that the supply is usually rationed, with the timing of supply sometimes less favorable and/or the available hours inadequate for food production and processing—including milling, grinding, drying and storage. The situation often compels market actors to turn to generators (for which fuel cost are relatively higher) as alternative power source for their businesses (Ndem 2022; World Bank 2022). The increased costs of food production/processing are likely transferred to consumers in form of high food prices, and consequently diet cost. The results suggest that unaffordability is negatively associated with access to electricity and increased nightlight intensity (proxy for urbanization) (Table 3). This is in line with Bai et al., (2020) that finds greater affordability of healthy diet with increased access to electricity.

As noted earlier, although higher gender parity tends to move together with greater affordability of healthy diets, cost of healthy diet tends to rise with it. This tendency for cost of diets to rise with increased gender parity may be demand side related, and possibly a long-term phenomenon. For example, long-term progress toward increasing gender parity (female schooling) and college graduation rates may result in greater wage employment earnings for women and improvement in overall gross domestic products (GDP). This possible growth in income/GDP can potentially put an upward pressure on aggregate food demand (and by extension hike in food prices and diet cost) without a corresponding supply response. It is worth mentioning that in practice, food production is usually inelastic in response to a surge (rise) in food demand. Where the food system is weak and unable to simultaneously supply enough foods to match a rise in aggregate demand, the natural consequence is an increase in food prices (diet costs). Even at the micro (household) level, women could impact more on food demand especially when they are more empowered (and have greater control over income resources) as they generally tend to spend more on goods that enhance household nutrition and health. Given that the results indicate that increased gender

⁴ In addition to seeking to address the challenges of high cost of accessing electricity in the country, options to diversify electricity (energy) consumption to other low-cost sustainable electricity/power supply sources especially in the agrifood sector may be worthwhile pursing as a long-term strategy for lowering cost of diets.

parity has the tendency to co-exist with growth in diet cost, thinking the Nigeria's food systems in this reality would mean a sustained long-term effort toward expanding food production/supply and storage, minimizing food wastages/losses, and ensuring efficiency distribution across states and segments of the country to be able curtail any likely escalation in food costs (prices) as may be induced by national policy drive toward gender progress.

Discussion and conclusions

This work highlights the importance of subnational/state-level appraisal and monitoring of the CoHD. There are marked differences in food systems, the CoHD and extent of affordability across states. On the one hand, states in the southern zones appear to perform better than those in the north in the aggregate food system index (FSI) and its sub-component scores especially that of climate and environmental resilience, food production, and food markets and trade. On the other hand, a higher share (above the median) of households who cannot afford the healthy diet were from northern states, signaling correlations between higher FSI and affordability of a healthy diet. This points the need for more focused attention on resilience building for improved food systems in northern Nigeria. However, it should be noted that the FSI is a relative measure, meaning that in our study, weak states were compared with weaker states as the average FSI was only 45 and the range between 30 and 56. Hence, targeted action toward improving the various food systems components even among the seemingly better performing states should be pursued to prevent a down spiral food systems performance in the zones.

There are cases where unaffordability remains high in the face of comparatively lower cost healthy diets and vice versa, highlighting the need for more efficient and equitable food supply systems. Low affordability of healthy diets reflects insufficient purchasing power and the need for higher incomes (FAO et al. 2020). As has been emphasized by other authors (FAO et al. 2020) and was observed in our study, populations with higher per capita food expenditures (reflecting higher incomes) have fewer households unable to afford healthy diets, even where the cost is relatively higher. In Nigeria, households with a head involved in agriculture only income generating activities have the highest rates of poverty, regardless of whether the head is male or female, and regardless of whether the household lives in an urban or rural area (NBS 2020b). This implies that the CoHD is most unaffordable among households with livelihoods dependent on food production. Increasing the incomes of food producers will therefore have to occur concurrently with affordable prices of nutritious foods, alongside support to agricultural households for own production of diverse foods and market integration. Support to food producers can include leveraging technology and innovation in food production, minimizing seasonality in food production, reducing pre-harvest and postharvest losses, and increasing/improving market access for food producers (FAO 2017).

The positive relationship between FSI and the CoHD, although not strong, seems to suggest food supply chains are not sufficiently efficient and/or effective. Food supply chains include agricultural production systems, as well as storage, postharvest

handling, transportation, and marketing systems (FAO et al. 2020). In the short term, actions that encourage greater market integration across the country should be harnessed so that food prices are similar across states and the CoHD is reduced in states where it is currently high. In the medium- to long-term, it is necessary to implement policies and actions to improve the supply chain of a variety of food items within each food group. The unaffordability of healthy diet implies a need for actions that improve the supply chain of such foods and reduce their costs for the poor-who often have the least access. For example, nutritious food groups such as fruits and vegetables and animal source foods are highly perishable and may not be sold in community markets because demand is low and/or there is a lack of storage infrastructure (de la Peña and Garrett 2018). Regular physical access to such foods may therefore be limited for households who do not live close to markets where such items are sold, or transportation costs to markets could prohibitively increase. Other studies have found that distance to markets is a barrier to fruit and vegetable consumption, including in Nigeria (De Filippo et al. 2021). Findings of this study suggest that achieving affordable healthy diets would require stepping up actions toward food systems transformation and improving, among others, access to basic services (such as good roads and electricity), increased presence of financial services (such as rural banks), greater access to information and communications services (mobile phone subscription rates and increased radio/television station coverage), facilitating more favorable and predictable business environment, and promoting women empowerment (through education).

As reflected in the varying dimensions of the FSI, cost and affordability of healthy diets, and situation with the assessed food system drivers, the particular actions needed to improve food systems across states will vary. State peculiarities in terms of comparative and competitive advantage in relation to structural drivers, food production, trade and markets as well as climate and environmental resilience will need to be considered in targeting action. There are several national frameworks that aim to build resilient food systems, including the National Climate Change Policy for Nigeria 2021–2030; National Agricultural Technology and Innovation Policy 2022–2027; and Implementation Strategy of the National Pathways for Food Systems Transformation in Nigeria 2023–2030. There is also a National Development Plan 2021–2025 that addresses food systems considerations as well as structural drivers. However, Morgan and Fanzo (2020) report that actions across various food system-related policies in Nigeria are siloed, creating limited policy coherence and potential negative feedback loops that harm food systems overall. Other authors (Ecker et al. 2021; Bizikova et al. 2022; FAO et al. 2022) have highlighted that state policies and strategies are not as comprehensive as national documents, and there is generally limited coherence between frameworks developed at the federal and state levels. The findings in our study emphasize the need for policy coherence across food systems dimensions and structural drivers, as well as the need to ensure that states do not merely adopt national frameworks but actively tailor it to the state situation with food systems dimensions and drivers.

Key leverage points that have been identified for improving overall food systems performance in Nigeria, with varying degrees of magnitude across states, include, among others, increased agricultural productivity through improved inputs, irrigation infrastructure, and mechanization; employment in micro-enterprises, and improving the movement of food through infrastructure interventions in roads, electricity, storage, and communication technologies, to improve market functioning and food value chains (Bizikova et al. 2022). Considering electricity as a leverage point for instance, it is noteworthy that the new Electricity Act (signed into law in Nigeria in June, 2023) has the potential to substantially promote rural electrification, reduce or eliminate inefficiencies in electricity sector, and increase access to electricity across different states of the country. With increased access to more reliable and affordable electricity, farmers, processors, and other actors within the food systems will be able to employ modern technologies that can considerably enhance agricultural productivity, reduce post-harvest losses, and positively impact on food system performance and socio-economic development of the country.

The current National Policy on Micro, Small and Medium Scale Enterprises (MSME) (2021–2025) also has clear roadmap strategies to promote employment in microenterprises, including agri-food businesses. In a review conducted by Omonona et al (2023), strong political will to address infrastructural deficits in roads and stable electric grid, among others, is what is required to create the needed enabling environment that would catalyze employment (engagement) in micro enterprises, promote income generation and access to more affordable diets. With respect to nightlight intensity, access to mobile phone and radio and televisions penetration, it should be noted that although their abundance in an area may connote greater presence of infrastructure, industries, urban expansion and more economic opportunities, their density may not necessarily translate directly to improved food systems performance. It is crucial to concentrate more on interventions and investments that can more directly enhance the food systems through farm productivity improvement, reduction of post-harvest losses, adoption of sustainable agricultural practices, promoting farmers' access to markets, strengthening the supply chains, and action that will enhance health/nutrition outcomes, among others.

Last, concepts and indicator framework for measuring food systems performance are growing even though many of the suggested indicators are more suitable for crosscountry analysis (Fanzo et al. 2021; Fonteijn et al. 2022; Schneider et al. 2023; Ingram et al., 2023). Due to lack of sub-national or states level data, indicators used to construct the FSI in this study may not sufficiently capture some dimensions of the food system, limiting our ability to fully explain the associations between food system performance and the cost and affordability of healthy diets. Moreover, our observations (35 states and the federal capital territory) are quite small, restricting the types of analysis that we could conduct and possible inferences. The small number of observations are also due to lack of data, but in this case data at more disaggregated levels such as local government levels. Further, findings of this study call for further research on the extent to which some of the food system drivers such as access to electricity (including hours of access), crises/insecurity, governance/income generating capacity, etc. explains inequalities in terms of healthy diets affordability across states.

Table 4 Food systems indicators used in the study

Dimension	Indicator	Source of data
Food system components		
Food production (availability)	Average size in hectares of agricultural land owned by households that have agricultural land	Calculated from 2013 and 2018 Nigeria Demographic and Health Surveys
	Average cereal yield (tonnes per hectare) in DHS clusters in the state	International Food Policy Research Institute (IFPR) Advancing Research on Nutrition and Agriculture (ARENA) DHS-GIS Database https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/ DVN/OOIPRW.The data was dated 2010, hence the data for 2008 NDHS dusters were used
Food Markets & Trade (accessibility)	Consumer Price Index—Spatial and temporal deflator	NLSS 2018/19 by NBS
	Road network (road density)—total length of federal roads divided by total land area of a state	Annual Abstract of Statistics (2017) published by the National Bureau of Statistics
Food Consumption (Inclusiveness & affordability)	Per-capita expenditures	National Bureau of Statistics (NBS 2020)—2019 Poverty and Inequality in Nigeria: Executive Summary
	Gini-index of income inequality	National Bureau of Statistics (NBS 2020)—2019 Poverty and Inequality in Nigeria: Executive Summary
	% of population below national poverty line	National Bureau of Statistics (NBS 2020)—2019 Poverty and Inequality in Nigeria: Executive Summary
Food Governance (Public Policies & Private Investment): Ease of doing business index	Number of small and medium enterprises (SMEs) per 100 people, 2017	NBS 2017 National survey of micro, small and medium enterprises (MSMEs) 2017
	% Share of total cases crimes/ reported offences share over country total, 2016 (Crimes include: Offence against persons; Offence against properties; Offences against lawful authority; and Local Acts/laws that cannot be enforced outside Nigeria)	National Bureau of Statistics, Nigeria https://nigeria.opendataforafrica.org/cgijuze/crime-statstics-reported-offen ces-by-type-and-state-2016

~ ~ ~		
Dimension	Indicator	Source of data
Food system outcomes		
Climate & Environmental resilience outcomes	Herfindahl index, data for 2010	International Food Policy Research Institute (IFPRI) Advancing Research on Nutrition and Agriculture (AReNA) DHS-GIS Database https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/ DVN/OQIPRW
	Average tree/forest coverage	International Food Policy Research Institute (IFPRI) Advancing Research on Nutrition and Agriculture (AReNA) DHS-GIS Database https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/ DVN/OQIPRW
	Average annual precipitation (mm/year) in DHS clusters in each state. Annual precipitation for each state was calculated (from the sum of monthly precipitation) as the mean annual precipitation in the state, using precipitation data from 2008, 2013, and 2018	International Food Policy Research Institute (IFPRI) Advancing Research on Nutrition and Agriculture (AReNA) DHS-GIS Database https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/ DVN/OQIPRW
	Average soil organic carbon stock (tonnes per hectare) for depth interval 0 to 30 cm, in DHS clusters in the state	International Food Policy Research Institute (IFPRI) Advancing Research on Nutrition and Agriculture (AReNA) DH5-GIS Database https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/ DVN/OQIPRV
Other indicators/drivers		
Internally generated revenue per capita		NBS 2017 Annual Abstract of Statistics, 2017 (based on the 2015/16 GHS panel)
Share of households with access to electricity		NBS 2018/19 NLSS
Rate of mobile phone subscription		Based on NBS 2018/19 NLSS
Number of radio and television stations per one million people		NBS 2017 Annual Abstract of Statistics, 2017 (based on the 2015/16 GHS panel)
Total employment in microenterprises as share of the population		NBS 2017 National survey of micro, small and medium enterprises (MSMEs) 2017
The number of deposit banks per million people		Based on NBS 2017 Annual Abstract of Statistics, 2017 (based on the 2015/16 GHS panel)
Average nightlight intensity, 2013		"International Food Policy Research Institute (IFPRI) Advancing Research on Nutrition and Agriculture (AReNA) DHS-GIS Database https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/ DVN/OQIPRW"
Gender parity in secondary school net attendance ratio		2018 Nigeria Demographic and Health Survey
The table builds on proposed dimensions and indicators by van Berku	m and Ruben (2021)	

	Food system index	Food system	n scores acros	ss dimensions		
	Aggregate score	Food production	Food markets & Trade	Food consumption	Food governance	Climate & environmental resilience
Abia	46	33	41	24	80	53
Abuja	37	10	19	47	71	36
Adamawa	34	24	31	40	55	22
Akwa Ibom	43	16	40	42	64	54
Anambra	45	39	46	25	59	54
Bauchi	44	19	53	34	63	50
Bayelsa	50	64	0	40	53	91
Benue	45	40	43	38	63	39
Cross River	48	35	30	42	65	69
Delta	48	57	34	47	53	48
Ebonyi	53	36	50	42	90	45
Edo	53	76	24	38	79	50
Ekiti	54	67	52	38	61	54
Enugu	47	35	40	31	62	66
Gombe	43	45	44	47	60	18
lmo	50	50	36	30	65	68
Jigawa	40	42	32	42	68	17
Kaduna	50	62	52	50	64	24
Kano	43	63	48	38	52	12
Katsina	30	28	29	29	57	8
Kebbi	40	45	45	38	56	15
Kogi	42	59	30	24	59	40
Kwara	44	62	40	25	70	24
Lagos	44	33	69	41	32	45
Nassarawa	47	37	28	31	99	41
Niger	41	33	38	38	66	31
Ogun	44	40	47	33	69	32
Ondo	49	63	36	28	70	50
Osun	52	68	57	24	79	29
Оуо	56	78	46	42	84	30
Plateau	51	61	35	65	65	28
Rivers	50	46	31	38	57	79
Sokoto	35	39	29	43	55	8
Taraba	47	37	23	52	62	60
Yobe	36	59	25	37	49	11
Zamfara	38	49	27	31	62	20
Mean	45	46	37	38	64	39
Median	45	43	37	38	63	40

Table 5 Food system component scores and the aggregate index by state

See Figs. 7, 8, 9, 10, 11, 12, 13 and 14.



Fig. 7 The relationship between income generating capacity (2016) and the Cost and Affordability of a Healthy Diet across Nigerian States



Fig. 8 The relationship between access to electricity (2019) and the Cost and Affordability of Healthy Diet across Nigerian States



Fig. 9 The relationship between mobile phone subscription rate (2019) and the Cost and Affordability of Healthy Diet across Nigerian States



Fig. 10 The relationship between number of radio & TV stations per 1 million people (2016) and the CoRD and Affordability across Nigerian States



Fig. 11 The relationship between total employment in microenterprises as share of population (2017) and the CoRD and Affordability across Nigerian States



Fig. 12 The relationship between number of deposit banks per million people (2016) and the CoRD and Affordability across Nigerian States



Fig. 13 The relationship between average nightlight intensity (2013) and the CoRD and Affordability across Nigerian States



Fig. 14 The relationship between gender parity in secondary school net attendance ratio (2018) and the CoRD and Affordability across Nigerian States

Abbreviations

AFE	Adult female equivalent
CoAHD	Cost and affordability of healthy diets
CoHD	Cost of healthy diets
CPI	Consumer Price Index
EA	Enumeration area
FAO	Food and Agriculture Organization
FBDG	Food-based dietary guideline
FCT	Federal capital territory
FSI	Food system index
HDB	Healthy Diet Basket
ICT	Information and communication technologies
NBS	Nigeria Bureau of Statistics
NLSS	Nigeria Living Standards Survey
SCP	Structure-conduct-performance
SDGs	Sustainable Development Goals
SME	Small and medium enterprises

Acknowledgements

We thank Dr. Adeyinka Onabolu (FMARD, GAIN) and Dr. Victor Ajieroh (Praisegate Services and Consult, Ikeja, Lagos, Nigeria) for their feedback on the earlier results and background note leading to this paper.

Author contributions

TA and DM originated the idea; DM, OA, DA compiled relevant data; DM, OA, RG, DA, TA, AH developed methodology for data analysis. RG and AH identified composition of the Healthy Diet Basket; DM analyzed the data and wrote the first draft together with OA and DA. DM, OA, RG, DA, TA, AH proofread the draft and modified technical aspects. All authors improved the discussion of results and write-up of the manuscript. All authors read and approved the final manuscript.

Funding

This study was funded by the CGIAR research programme on Agriculture for Nutrition and Health (A4NH) and Sustainable Healthy Diets (SHiFT).

Availability of data and materials

The authors declare that data shall be provided upon request.

Declarations

Competing interests

The authors declare that they have no competing interest.

Received: 12 April 2023 Revised: 20 June 2023 Accepted: 27 June 2023 Published online: 03 July 2023

References

- Akande A, Costa AC, Mateu J, Henriques R (2017) Geospatial analysis of extreme weather events in Nigeria (1985–2015) using self-organizing maps. Adv Meteorol. https://doi.org/10.1155/2017/8576150
- Ali R, Barra AF, Berg CN, Damania R, Nash J, Russ J (2015) Transport infrastructure and welfare: an application to Nigeria. Policy research working paper, WPS 7271, World bank, Washington
- Aterido R, Hallward-Driemeier M (2010) The impact of the investment climate on employment growth. Does sub-Saharan Africa mirror other low-income regions? Policy research working paper 5218; The World bank
- Audretsch DB, Heger D, Veith T (2015) Infrastructure and entrepreneurship. Small Bus Econ 44:219–230. https://doi.org/ 10.1007/s11187-014-9600-6

Bai Y, Alemu R, Block SA, Headey D, Masters WA (2020) Cost and affordability of nutritious diets at retail prices: evidence from 177 countries. Food Policy. https://doi.org/10.1016/j.foodpol.2020.101983

Bai Y, Costlow L, Ebel A, Laves S, Ueda Y, Volin N, Zamek M, Herforth A, Masters WA (2021) Retail consumer price data reveal gaps and opportunities to monitor food systems for nutrition. Food Policy 104:102148. https://doi.org/10. 1016/j.foodpol.2021.102148

Bai Y, Herforth A, Masters WA (2022) Global variation in the cost of a nutrient-adequate diet by population group: an observational study. Lancet Planet Health 6(1):e19–e28. https://doi.org/10.1016/S2542-5196(21)00285-0
 Bain JS (1959) Industrial organization. Wiley, New York

van Berkum S, Ruben R (2021) Exploring a food system index for understanding food system transformation processes. Food Sec 13:1179–1191. https://doi.org/10.1007/s12571-021-01192-6

- Biswas RK (2016) An economic analysis of crop diversification under inorganic and organic farming in West Bengal. Int J Bioresour Sci 3(1):33–38
- Bizikova L, De Brauw A, Eber Rose M, Laborde D, Motsumi K, Murphy M, Parent M, Picard F, Smaller C (2022) Achieving Sustainable food systems in a global crisis: Nigeria ceres2030 deep dives into the nexus of food systems, climate change, and diets. International institute for sustainable development. https://www.iisd.org/system/files/2022-09/ sustainable-food-systems-global-crisis-nigeria.pdf [Accessed on 11 June 2023]

Brinkman HJ, de Pee S, Sanogo I, Subran L, Bloem MW (2010) High food prices and the global financial crisis have reduced access to nutritious food and worsened nutritional status and health. J Nutr 140(1):153S-161S. https://doi.org/10.3945/jn.109.110767

Candelise C, Saccone D, Vallino E (2021) An empirical assessment of the effects of electricity access on food security. World Develop. https://doi.org/10.1016/j.worlddev.2021.105390

de la Peña I, Garrett J (2018) Nutrition-sensitive value chains: A guide for project design. Rome: international fund for agricultural development (IFAD). https://www.ifad.org/en/web/knowledge/publication/asset/40805038

Development initiatives (2017) Global nutrition report 2017: nourishing the SDGs. Development initiatives, Bristol Echendu AJ (2020) The impact of flooding on Nigeria's sustainable development goals (SDGs). Ecosyst Health Sustain 6(1):1791735. https://doi.org/10.1080/20964129.2020.1791735

Ecker O, Brown T, Andam KS (2021) Transforming Nigeria's agrifood system: wealthier, but also healthier. International food policy research institute. https://www.jstor.org/stable/resrep46750 [Accessed on 11 June 2023]

Economist intelligence unit (EIU) (2019) Global food security index 2019. Strengthening food systems and the environment through innovation and investment. The economist intelligence unit limited. https://impacteconomist.com/ sustainability/project/food-security-index/Resources

- Eifert B, Gelb A, Ramachandran, V (2005) Business environment and comparative advantage in Africa: evidence from the investment climate data. WP56, Center for global development
- FAO, European union, CIRAD (2022) Food systems profile Nigeria. Catalysing the sustainable and inclusive transformation of food systems. Rome, Brussels and Montpellier, France. https://doi.org/10.4060/cc3380en
- FAO, IFAD, UNICEF, WFP, WHO (2020) The state of food security and nutrition in the world 2020. Transforming food systems for affordable healthy diets. Rome, FAO
- FAO (2017) The future of food and agriculture alternative pathways to 2050. Rome, FAO. https://www.fao.org/3/CA155 3EN/ca1553en.pdf
- Fan S, Chan-Kang C (2004) Road development, economic growth, and poverty reduction in China. DSGD discussion paper No. 12, international food policy research institute, Washington
- Fanzo J, Haddad L, Schneider KR, Bene C, Covic NM, Guarin A et al (2021) Viewpoint: rigorous monitoring is necessary to guide food system transformation in the countdown to the 2030 global goals. Food Policy 104:102163. https://doi.org/10.1016/j.foodpol.2021.102163

Federal ministry of environment (2021) Nigeria's adaptation communication to the United Nations framework convention on climate change. https://unfccc.int/sites/default/files/resource/Nigeria%20Final%20ADCOM%20Report.pdf

- De Filippo A, Meldrum G, Samuel F, Tuyet MT et al (2021) Barrier analysis for adequate daily fruit and vegetable consumption among low-income residents of Hanoi Vietnam and Ibadan Nigeria. Global Food Sec 31:100586. https://doi. org/10.1016/j.gfs.2021.100586
- Fonteijn HM, van Voorn GA, de Steenhuijsen Piters B, Hengeveld GM (2022) The ABCD of food systems resilience: an assessment framework. Wageningen University & Research, Wageningen
- HLPE (2017) Nutrition and food systems. A report by the high level panel of experts on food security and nutrition of the committee on world food security, Rome. http://www.fao.org/3/i7846e/i7846e.pdf
- Han J, Kamber M, Pei J (2012) Data mining the morgan kaufmann series in data management systems. Chapter 3. Pp 83–124 https://doi.org/10.1016/B978-0-12-381479-1.00003-4
- Herforth A, Bai Y, Venkat A, Mahrt K, Ebel A, Masters WA (2020) Cost and affordability of healthy diets across and within countries. Background paper for the state of food security and nutrition in the world 2020. FAO, Rome
- Herforth A, Venkat A, Bai Y, Costlow L, Masters WA (2022) Methods and options to monitor the cost of a healthy diet globally background paper for the state of food security and nutrition in the world 2022. FAO agricultural development economics working paper 22–03. Rome, FAO. https://doi.org/10.4060/cc1169en
- Hornberger K, Battat J, Kusek P (2011) Attracting FDI: how much does investment climate matter? Viewpoint, note number 327. The World Bank
- limi A (2008) Effects of improving infrastructure quality on business costs: evidence from firm-level data. Policy research working paper; No. 4581. World Bank, Washington
- Ingram J, Bellotti W, Brklacich M et al (2023) Further concepts and approaches for enhancing food system resilience. Nat Food 4:440–441. https://doi.org/10.1038/s43016-023-00762-5
- International food policy research institute (IFPRI) (2016) Global nutrition report 2016: from promise to impact: ending malnutrition by 2030. Washington
- International crisis group (2020) Violence in Nigeria's North West: rolling back the Mayhem. Africa report N°288. https:// reliefweb.int/sites/reliefweb.int/files/resources/288-violence-in-nigerias-north-west.pdf
- Ismail Z (2021) Interaction between food prices and political instability. K4D Helpdesk report. Institute of development studies. https://doi.org/10.19088/K4D.2021.091
- Jaiyeola AO, Choga I (2020) Assessment of poverty incidence in Northern Nigeria. J Poverty 25(5):1-18
- Khanani RS, Adugbila EJ, Martinez JA, Pfeffer K (2021) The impact of road infrastructure development projects on local communities in Peri-Urban areas: the case of Kisumu, Kenya and Accra Ghana. Int J Commun Well-Being 4:33–53. https://doi.org/10.1007/s42413-020-00077-4
- Marshall Q, Fanzo J, Barrett CB, Jones A D, Herforth A, McLaren R (2021) Building a global food systems typology: a new tool for reducing complexity in food systems analysis. Front Sustain Food Syst. https://doi.org/10.3389/fsufs.2021. 746512
- Masters WA, Djurfeldt AA, De Haan C, Hazell P, Jayne T, Jirsrom M, Reardon T (2013) Urbanization and farm size in Asia and Africa: implications for food security and agricultural research. Glob Food Sec 2(3):156–165
- Meijer JR, Huijbregts MAJ, Schotten KCGJ, Schipper AM (2018) Global patterns of current and future road infrastructure. Environ Res Lett 13:064006
- Mekonnen DA, Akerele D, Achterbosch T, de Lange T, Talsma EF (2021a) Affordability of healthy and sustainable diets in Nigeria. Front Sustain Food Syst 5:726773. https://doi.org/10.3389/fsufs.2021.726773
- Mekonnen DA, Trijsburg L, Achterbosch T, Brouwer ID, Kennedy G, Linderhof V, Ruben R, Talsma EF (2021b) Food consumption patterns, nutrient adequacy, and the food systems in Nigeria. Agric Food Econom 9(1):1–21. https://doi. org/10.1186/s40100-021-00188-2
- Morgan AE, Fanzo J (2020) Nutrition transition and climate risks in Nigeria: moving towards food systems policy coherence. Current Environmental Health Reports 7:392–403
- Nakamura S, Bundervoet T, Nuru M (2019) Rural roads, poverty, and resilience : evidence from Ethiopia policy research working paper; No. 8800. World Bank, Washington
- National Agricultural Extension and Research Liaison Services (NAERLS) and Federal Ministry of Agriculture and Rural Development (FMARD) (2020) Wet Season agricultural performance in Nigeria. NAERLS Press, Zaria
- National Bureau of Statistics (NBS) (2020b) Nigeria living standards survey. A survey report by the Nigerian National Bureau of statistics (in collaboration with the World Bank) (2018/2019)
- National Bureau of statistics (NBS) (2020c) Basic information document. Nigeria living standards survey 2018/19 National Bureau of statistics (NBS) (2017) Annual abstract of statistics, 2017 Abuja, Nigeria: National Bureau of statistics National Bureau of statistics (NBS) (2020a) 2019 Poverty and inequality in Nigeria: executive summary. Abuja, Nigeria: National Bureau of statistics
- National Bureau of statistics (NBS) (2021a) Selected food price watch. Document available at https://www.nigerianstat. gov.ng/pdfuploads/Selected_Food_Price_Watch_JUNE_2021a.pdf Accessed 19 May, 2022
- National Bureau of statistics (NBS) (2021b) Selected food price watch. Document downloaded at https://nigerianstat.gov. ng/elibrary/read/1241163. Accessed 19 May, 2022
- Ndem A (2022) Four factors responsible for rising food prices in Nigeria in 2022. Centre For journalism innovation, development. https://thecjid.org/four-factors-responsible-for-rising-food-prices-in-nigeria-in-2022/ [Accessed on 8 Feb 2023]
- Ndukwe OJ, Allison P (2021) Good governance and ease of doing business in Nigeria: problems and prospects. Int J Acad Manag Sci Res 5(1):88–96
- Olagunju T E, Adewoye SO, Adewoye AO, Opasola OA (2021) Climate change impacts on environment: human displacement and social conflicts in Nigeria. In: 4th international conference on science and sustainable development (ICSSD 2020). IOP Conf. series: earth and environmental science 655 (2021) 012072. https://doi.org/10.1088/1755-1315/655/1/012072

- Omonona, B T, Amadi, G, Liverpool-Tasie, L S O (2023) A Review of the 2021–2025 National policy on micro, small and medium scale enterprises (MSMEs) in Nigeria. https://www.canr.msu.edu/fsg/projects/RSM2SNF%20MSME%20Rev iew%2013-04-2023.pdf [Accessed on 19 June 2023]
- Schneider K, Fanzo J, Haddad L, Herrero M, et al. (2023) The state of food systems worldwide: counting down to 2030. https://doi.org/10.48550/arXiv.2303.13669 [Accessed May 30, 2023]
- Shittu A, Akerele D, Haile M (2018) Effects of food price spikes on household welfare in Nigeria. ZEF-Discussion papers on development policy, (248). University of bonn, center for development research (ZEF), Bonn

Venables AJ (2015) Making cities work for development, IGC growth brief series 002. London World bank (2022) Nigeria development update december 2022 - Nigeria's choice (English). Washington, DC. Bank

- Group. http://documents.worldbank.org/curated/en/099305012142215802/P179906004b7c80340a74d0ee78629 53b8f
- Zomer RJ, Neufeldt H, Xu J, Ahrends A, Bossio D, Trabucco A, van Noordwijk M, Wang M (2016) Global tree cover and biomass carbon on agricultural land: the contribution of agroforestry to global and national carbon budgets. Sci Rep 6(1):29987

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Submit your manuscript to a SpringerOpen[™] journal and benefit from:

- Convenient online submission
- ► Rigorous peer review
- Open access: articles freely available online
- ► High visibility within the field
- Retaining the copyright to your article

Submit your next manuscript at > springeropen.com