Analyzing the drivers of a balanced diet: Evidence from Burkina Faso*

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Draft 26 February 2021: please do not cite or reference

Abstract

Despite the economic growth achieved by many developing countries, undernutrition is still a widespread problem, with the diet of millions of poor individuals failing to provide adequate amounts of crucial macro- and micro-nutrients necessary for the human body. This study examines the correlates of a balanced diet using data from Burkina Faso. In addition to the often-used Household Dietary Diversity Score (HDDS), the Healthy Food Diversity Index (HFDI) is used to measure household dietary diversity. While the HDDS has been identified as a valid measure of dietary diversity correlated with dietary quality, it has some shortcomings. First, it does not account for the actual quantities of food consumed and, second, it places equal weight on the consumption of different food groups, without accounting for the fact that not all food groups are equally nutritious. The HFDI mitigates this challenge by embedding three critical aspects of a healthy diet –number, distribution, and health value of food items. Our estimates confirm that household size, location, sex of household head, durable ownership, production diversity, and market access all are significantly associated with the consumption of a balanced diet.

* Potential target journals: *Food Policy, Food Security, or Food and Nutrition Bulletin*

We would like to thank Odilia Bermudez and all staff of the INDDEX Project, which is implemented by the Tufts University Gerald J. and Dorothy R. Friedman School of Nutrition Science and Policy with funding from the Bill & Melinda Gates Foundation. All errors are our own responsibility.

1 Introduction

The importance of balanced diet for growth, development, and maintenance of bodily functions has been comprehensively established (US-DHHS, 2012; WHO, 2019a). The World Health Organization (WHO) recommends that children and adults should consume a variety of different foods, including staples (e.g. cereals, pulses, or tubers), vegetables, fruit and animal sourced foods (e.g. meat, eggs, or milk) (WHO, 2019b). Quantitatively, this translates to consuming at least 400g (i.e. five portions) of fruit and vegetables per day, excluding potatoes, sweet potatoes, cassava, and other starchy roots. The WHO adds that less than 10% of total energy intake should be derived from free sugars and less than 30% of total energy intake should be derived from fats. Finally, the amount of salt consumed should be less than 5g per day. Following a diet based on these guidelines, children and adults can obtain an adequate amount of essential macro and micronutrients. For the purpose of our analysis, we define a diet *balanced* purely based on the variety of food items consumed and their potential nutrition value, regardless of the absolute amount of food items consumed. That is, in our definition we equate a balanced diet with *healthy* and *adequate*, assuming that individuals have an adequate -and not excessive- intake of calories and nutrients.

The consumption of an adequate, balanced, and healthy diet is especially important for children's development and aids older adults to have healthier and more active lives. While subjective perceptions of a healthy diet vary across regions (Banna, Gilliland, Keefe, & Zheng, 2016) and over time (Imamura et al., 2015), the common idea is that it is a diet comprising a wide variety of foods in correct amounts and proportions (WHO, 2018). High-variety diets are typically correlated with overall better health outcomes measured in terms of the mean adequacy ratio[1] (MAR) (Torheim et al., 2004), as well as more "visible" measures such as stunting rates (Rah et al., 2010) based on height-for-age z-scores (Arimond & Ruel, 2004) among children.

In this study, we analyze the correlates of a balanced diet based on household-level food consumption data from Burkina Faso. As per our definition above, we will measure household-level balanced diet based on diversity, as well as the nutritional content of food items. Our strategy builds upon previous work by Steyn, Nel, Nantel, Kennedy, & Labadarios (2006) (food

[1] The Mean Adequacy Ratio (MAR) is a member of the class of indicators used to evaluate individual intake of nutrients. This index quantifies the overall nutritional adequacy of a population based on an individual diet using the current recommended allowance for a group of nutrients of interest.

variety score and dietary diversity score) and Kim, Haines, Siega-Riz, & Popkin (2018) (diet quality index across countries) on similar type of data. Our study aims to improve the outcome indicator by not only looking at food item diversity, but also incorporating the dimension of relative quantities of consumption and the associated nutrition factor of each food group. Distinguishing the nutritional component of each food group is important, as the consumer can obtain higher nutrients from fruit and vegetables consumption, as opposed to sweet beverages.

2 Literature Review

An ideal balanced diet incorporates diversity with substantial consumption of fruit and vegetables along with some animal sourced foods. Such diet provides an adequate amount of nutrients necessary for bodily growth, development and maintenance. Unbalanced diet has been linked with impaired muscle, cardiac, respiratory, gastrointestinal and immune functions (among others) (Saunders & Smith, 2010). Malnutrition effects can be more pronounced for children, where inadequate nutrition can result in stunting and negatively impact several subsequent outcomes including educational attainment and earnings (Alderman, Hoddinott, & Kinsey, 2006). Large benefits in improving nutrition have been estimated: African economies for example can recover 3 to 16 per cent of GDP annually should they eliminate malnutrition (Hoddinott, 2016).

An important aspect of a nutrition analysis is the unit and reference period for which food consumption data are collected. When data are collected at the household level, it is difficult to draw inference about individual level outcomes without making assumptions about intra-household distributions. An analysis that assumes equitable distribution determined by caloric needs based on either per-capita or per-adult equivalent (AE) could produce biased results, since intrahousehold inequality has been documented across several countries (Chiappori & Meghir, 2015), especially for vulnerable groups that are more likely to receive a smaller share of resources (Doss, 2013). While individual level disaggregation through per capita or AE calculations offer easy solutions to this problem, the level of accuracy varies on a case-by-case basis (Bromage et al., 2018; Karageorgou et al., 2018; Sununtnasuk & Fiedler, 2017).

Since the aim of our paper is to better capture dietary diversity looking beyond the HDDS (Swindale & Bilinsky, 2006), we first need to assess whether or not that particular item was consumed during the reference period and then account for the relative quantities of consumption of each food item, using the Berry Index (Berry, 1971)[2]. Although this index incorporates both diversity and relative quantities of each food group consumed, it applies equal weights to food groups and does not embed the fact that healthier foods should be consumed in greater amounts. Observing this limitation, Drescher, Thiele, & Mensink (2006) use dietary guidelines from the German Nutrition Society (DGE), which propose that an healthy diet should comprise 73% of plant foods, 25% of animal foods and 2% of fats and oils[3,4] to calculate a "health factor" to assign to each food group. Once calculated, these health factors are then multiplied with relevant (corresponding to their food group) individual food item shares to obtain the HFDI. Unfortunately, nationally endorsed dietary recommendations are unavailable for Burkina Faso, hence we use a consumption set identified to provide adequate nutrition for women of reproductive age (WRA), to impute the health factors of each food group, and to consequently obtain the household-level HFDI (see below).

Ample evidence showing the importance of various socioeconomic factors that affect availability and accessibility of food exists. Hiza, Casavale, Guenther, & Davis (2013) find that amongst Americans, Hispanics have better quality diets than Blacks and Whites, and that overall adult diet quality improves with income. Utilizing the Healthy Eating Index (HEI), Forshee & Storey (2006) find that family income is positively associated with HEI. A study from Benin finds that socioeconomic status is positively associated with share of energy derived from fat (Sodjinou, Agueh, Fayomi, & Delisle, 2009). Intrahousehold gender dynamic is found to be significant in Bangladesh, where households with higher female education are associated with better dietary quality. Controlling for total expenditure, female household headship is however associated with lower dietary quality (Rashid, Smith, & Rahman, 2011).

In Burkina Faso, literature suggests that education level of the household head is linked to household- and individual-level dietary diversity (Becquey et al., 2012). Households with higher agricultural income seem to enjoy better quality diets in Malawi (Jones, 2016). A positive association has also been documented between household dietary quality and production

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[2] In its original design, the index was intended to measure corporate diversification. It is formulated as: $1 - \sum_{i=1}^{n} p^2$, where p_i is the ratio of the firm's output in the i^{th} industry to the firm's total output in n industries. However, as a general index of diversity, it has been used in studies relating to economic food diversity (Stewart & Harris, 2005; Thiele & Weiss, 2003).

[3] The percentages refer to quantity of food consumed and have been imputed by the authors from the German nutrition circle proposed by the DGE.

[4] The recommendations proposed by DGE are for the German population and, as such, may not apply to the rest of world. They are based on a general consumption set rather than caloric content. However, researchers have approximated a possible consumption set based on weight of the food items (Oberritter, Schäbethal, Von Ruesten, & Boeing, 2013).

diversity in Malawi (Jones, Shrinivas, & Bezner-Kerr, 2014) as well as Indonesia, Kenya, and Ethiopia (Sibhatu, Krishna, & Qaim, 2015). Ease of access to markets has also been found to play a significant role in the type of foods available for consumption (Koppmair, Kassie, & Qaim, 2017; Larsen & Gilliland, 2009). This study builds on the work by Somé & Jones (2018) by not only incorporating food diversity as a measure of healthy food consumption, but also controlling for the relative proportions of each food item consumed and taking into account the "health factor(s)" of food groups for a better measurement of dietary quality.

3 Setting, data, and variables

3.1 Study setting

Burkina Faso is overwhelmingly poor and rural, with an agriculture-dominant economy. In 2012, average per capita income was $460, and 44% of the population lived under $1.90 (in purchasing power parity) per capita/day (Nguyen & Dizon, 2017). Although the country has witnessed an improvement from 82% poverty rate in 1998 to 44% in 2014 (World Bank, 2018), considerable efforts need to be exerted to eradicate extreme poverty. Chronic undernutrition is rampant in Burkina Faso among both reproductive-age women and young children. For example, based on food consumption data collected from reproductive-age women and 24-hour recalls, Becquey & Martin-Prevel (2010) find adequate intake of Vitamin B-12, folate, riboflavin, and niacin among, respectively, 4%, 12%, 13%, and 20% of the sample. In several practical indicators, Burkina Faso performs quite poorly, with over 25% of children under 5 being stunted and 7.6% wasted (FAO, IFAD, UNICEF, WFP, & WHO, 2018). More than a fifth (21%) of the Burkinabe population was reported to be undernourished between 2015-2017 (FAO, IFAD, UNICEF, WFP, & WHO, 2018). This underlines the importance of determining which households in the country have access to a balanced diet and, consequently, good nutrition.

3.2 Data and variables

We use data from the 2014 Burkina Faso Continuous Multisectoral Survey (*Enquête Multisectorielle Continue*) (EMC 2014) conducted between January and December 2014. Data are nationally representative and were collected from all 45 provinces. A two-stage sampling technique was applied, with the first stage involving a random sampling of 905 enumeration zones using probability proportional to the number of households and the second stage involving the random sampling of 12 households per enumeration zone. A total of 10,860 households were included in the EMC with dietary consumption data collected across four periods corresponding to the different stages of the agricultural production cycle. On each visit, the household was asked about consumption of various items in the previous seven days. We utilize this information and several other socioeconomic and geographical variables to assess the determinants of dietary quality. While consumption quantity -in addition to expenditure- data were collected for all four periods, data from round two through four have not been publicly released and have therefore been excluded from this analysis. Consequently, we are unable to account for seasonality in our empirical modelling.

3.3 Index construction

Quantifying consumption expenditure and quantity using Household Consumption Expenditure Surveys (HCES) such as the 2014 Burkina Faso EMC is difficult in many ways. However, some literature (Fiedler et al. 2012 among others) has demonstrated the usefulness of HCES for food security and nutrition analysis. In this study we would like to highlight that HCES are also helpful for the calculation of dietary quality -in addition to quantity- indicators, which should be seen as complementary information to assess food security and nutrition, considering the data collection challenges inherent with this type of survey data for consumption and dietary analysis.

Swindale & Bilinsky (2006) define HDDS based on the consumption of the following 12 food groups: cereals; roots, tubers and plantains; pulses, legumes, nuts and seeds; vegetables; fruits; meat; fish and seafood; milk and dairy products; eggs; oils and fats; sugar/honey; and miscellaneous. The HDDS is the most commonly-used proxy of dietary quality and has been found to be correlated with caloric and protein adequacy, proportion of protein from animal sources and household income (Swindale & Bilinsky, 2006; Kennedy, Ballard, & Dop 2011). While a high HDDS score is associated with a healthy diet, it does not consider the relative quantities of food items consumed.

As per the definition of the index, we are only looking at whether a food group was consumed, as opposed to the quantities consumed of the different food groups. To illustrate the potential problem with this approach, we can consider the following hypothetical consumption set for household #1 (listed in food item – *food group* format): rice - *cereals* (600g), potatoes - *roots* (250g), beans - *legumes* (100g), spinach - *vegetables* (100g), apples - *fruits* (100g) and tilapia – *fish and seafood* (5g). This HDDS of this consumption set would be six. However, we notice that the household is consuming a relatively small amount of tilapia (*fish*), suggesting that HDDS is not accurately representing the diversity of the diet. Therefore, we would also need to consider the actual amount of food consumed to accurately represent household dietary diversity. Building on the shortcomings of HDDS, the Berry Index (Berry, 1971) is a useful indicator that controls for the actual quantities of individual food items. For a household k, it is defined as follows:

$$BI_k = 1 - \sum s_i^2 \qquad \text{Equation (1)}$$

Where $s_i = \frac{total\ quantity\ of\ food\ item_i}{total\ quantity\ across\ all\ food\ items}$ (food items consumed by each household k). According to this formulation, the measurement units in numerator and denominator should be expressed in the same metrics. (e.g. grams in our case). Following our example above, the Berry Index for this consumption set would be:

$$BI_1 = 1 - \left(\left(\frac{600}{1155}\right)^2 + \left(\frac{250}{1155}\right)^2 + \left(\frac{100}{1155}\right)^2 + \left(\frac{100}{1155}\right)^2 + \left(\frac{100}{1155}\right)^2 + \left(\frac{5}{1155}\right)^2\right)$$

$$BI_1 \cong 0.66$$

Now, let us consider the hypothetical consumption set of household #2, which is a slightly modified version of household #1: rice - *cereals* (550g), potatoes - *roots* (230g), beans - *legumes* (100g), spinach - *vegetables* (100g), apples - *fruits* (100g) and tilapia - *fish and seafood* (75g), for which the Berry Index is shown below:

$$BI_2 = 1 - \left(\left(\frac{550}{1155}\right)^2 + \left(\frac{230}{1155}\right)^2 + \left(\frac{100}{1155}\right)^2 + \left(\frac{100}{1155}\right)^2 + \left(\frac{100}{1155}\right)^2 + \left(\frac{75}{1155}\right)^2\right)$$

$$BI_2 \cong 0.71$$

For the same level of total consumption/weight, simply increasing the consumption of *tilapia* by 70 grams (reducing 50 grams of rice and 20 grams of potato consumption) produces a higher Berry Index while the HDDS is unchanged. Being able to weigh the relative proportions of each food item allows us to draw a more complete picture of the diversity in the diet. However, while dietary diversity measured by the Berry Index is higher for household #2, we cannot conclude that the second consumption set is necessarily healthier than the first. The shortcoming of the

Berry Index is in fact that we are assigning the same health value to each food item (as with the HDDS) while, ideally, a household should consume healthier foods in greater quantities. In other words, different food items should have different weights to determine the health value of a household diet. This is the improvement offered by the Healthy Food Diversity Index (HFDI) and defined for household k as follows:

$$HFDI_k = (1 - \sum s_i^2) hv_k \qquad \text{Equation (2)}$$

Where hv_k (health value) is defined as: $\sum hf_j s_i$;

s_i is as defined before, hf_j is the health factor of the food group j as calculated in the next section. In practical terms, the consumption quantity share of a food item *i* is multiplied by the heath factor of the food group *j* to which it belongs. For example, s_{rice} would be multiplied by $hf_{cereals}$. Mathematically, both the Berry Index and the HFDI are limited to be lower than one. As with the Berry Index, it is difficult to determine an ideal number of the HFDI, as it would depend on the consumption set based on which the health factors are determined in addition to the relative quantities of food items consumed. For example, it is possible that a household consumes only the food items associated to the highest health factors driving up the health value of the diet but, because of the polarized diet favoring only certain items over others, the HFDI would fall -as would the Berry Index- due to low diversity in consumption. For interpretation purposes, the higher the value of HFDI, the healthier and more diverse the diet. However, different values of the HFDI can be compared only if they have been calculated based on the same health factors and balanced consumption set.

3.3.1 Health factors

As mentioned, national food-based dietary guidelines are unavailable for Burkina Faso. The HFDI is founded on the idea that every food group is associated to a constant health factor, for a given consumption set. These health factors are determined based on a recommended consumption set associated with positive health outcomes along with adequate nutrient intake. For our analysis, we are relying on a consumption set which has been found to meet nutrient adequacy among women of reproductive age in Ouagadougou, Burkina Faso (Arimond, Vitta, Martin-Prével, Moursi, & Dewey, 2017). There are obvious caveats from the use of these data, covering dietary data for a specific female age group who reside in an urban area of the country, the capital. Though, as we will demonstrate, the absolute value of consumption of each food group is not a matter of concern as we are using the relative shares of each food group.

Table 1: Model Consumption Set

Food Category	Food Groups	75th Percentile (g/day)
Plant Foods	Grains (cereals)	662
Plant Foods	Roots, tubers, plantains	150
Plant Foods	Dried beans, pulses	126
Plant Foods	Nuts and seeds (including peanuts)	44
Plant Foods	Leafy green vegetables	110
Plant Foods	Other vegetables	184
Plant Foods	Fruit	360
Animal Foods	Dairy products	38
Animal Foods	Eggs	60
Animal Foods	Meat and poultry	68
Animal Foods	Organ meat	16
Animal Foods	Fish (large fresh or canned)	59
Animal Foods	Fish (dried)	6
Fats and oils	Fats and oils	40

Note: All values have been taken from Arimond et al. (2017).

Table 2: Recategorization based on HDDS food groups and Health Factor calculations

Food Groups	75th Percentile (g/day)	Food category	Food category		Food group proportion[c]	Health Factors[d]
			g[a]	proportion[b]		
Grains	662	Plants Foods	1,636	0.85	0.40	0.34
Roots, tuber, plantains	150				0.09	0.08
Pulses, legumes, nuts, and seeds	170				0.10	0.09
Vegetables	294				0.18	0.15
Fruits	360				0.22	0.19
Meats	84	Animal Foods	247	0.13	0.34	0.04
Fish and seafood	65				0.26	0.03
Milk and dairy products	38				0.15	0.02
Eggs	60				0.24	0.03
Oils and fats	40	Oils and fats	40	0.02	1.00	0.02
Beverages[1]	-	-	-	-	-	-
Miscellaneous[2]	-	-	-	-	-	-
Total (grams)	**1,923**		**1,923**			

[a]: Calculated as the total quantity of the relevant food category. For example, for the case of plant foods, it is the sum of grains, roots, tuber, plantains, pulses, legumes, nuts and seeds, vegetables and fruits.
[b]: Calculated as the ratio of the total quantity of each food category to the total quantity across all food categories. For example, for plant foods this ratio is: (1,636/1,923)≈0.85, where 1,636 is the total quantity of plant foods and 1,923 is the total quantity of food across all food categories.

[c]: Calculated as the ratio of the quantity of individual food groups within a food category to the total quantity of the food category. For example, for cereals, this would be calculated as: $(662/1{,}636) \cong 0.4$, where 662 is the total quantity of cereals and 1,636 is the total quantity of plant foods.
[d]: Health factors are calculated as the product of the food category proportion times the food group proportion. For example, for grains it would be: $0.85 \times 0.40 = 0.34$
[1]: Includes beers, wines, spirits, etc.
[2]: Includes spices, seasonings, etc.

Table 2 shows that based on the model consumption set of Table 1, the imputed "recommended" diet is comprised of 85% of plant foods, 13% of animal foods and 2% of oils and fats. While this diet might appear to be drastically different from the German recommendation, the values of interest for our analysis are solely the health factors. Additionally, we note that the food groups identified as beverages and miscellaneous (e.g. beer, coffee, tea, spices) have been omitted from this exercise and as such are not associated to any health factors, given their negligible positive impacts on the human body. Therefore, we do not expect their omission to significantly bias our results.

4 Statistical models

The following model is estimated to assess the determinants of a balanced diet:

$$y_i = f(\boldsymbol{X}_i, \boldsymbol{B}_i) + e \qquad \text{Equation (3)}$$

where y_i refers to the different dietary diversity indicators for household i, either the simple count of unique food items consumed, HDDS, Berry Index, or the HFDI as defined above.

$\boldsymbol{X}_i$ refers to the household characteristics, and $\boldsymbol{B}_i$ refers to biophysical variables associated to household i, and e is the model error. $\boldsymbol{X}_i$ includes several control variables including household size (measured as number of household members, unadjusted for adult equivalent scales), location (urban/rural), gender and education level of the household head, household asset ownership (measured through the number of unique durables owned), production diversity[5] (measured through the number of unique crops grown by the household), agricultural equipment owned (distinct number of equipment) and market access (measured as time taken to travel to the nearest market). Additionally, we shall be controlling for region fixed effects. $\boldsymbol{B}_i$ controls for the

[5] Unfortunately, the 2014 Burkina Faso EMC did not collect information about livestock by-products. Therefore, production figures do not account for animal sourced foods, which might lead to underestimation in production values.

mean and coefficient of variation of precipitation and temperature for the 2013 cropping season (June through December) as they are likely to determine availability and accessibility of food in addition to controlling for historic mean and variation of precipitation and temperature. Being the Berry Index and HFDI continuous variables -ranging between 0 and 1-, we run an OLS model. On the other hand, since HDDS is a count variable -ranging between 0 and 12- we run a Poisson model. Estimates control for multistage clustered sampling design, with robust standard errors clustered at the enumeration area level.

5 Results and discussion

The descriptive summary shows an average of 7 members per household with more than 85% of households headed by males (Table 3). More than three fourths of household heads have not completed primary education with more than 70% of households residing in rural areas. The average household land ownership is about 2.4 hectares. On average, households produce 1.24 different food groups and 2.26 different food items, with only 6% of them producing any vegetable. Average harvest -computed on the full sample including also non-producers- during the reference period is about 279 kg. The average household owns approximately five unique durable items. At national level, households earn on average over 28,000 CFA from off-farm activities and derive more than 30% of their consumption from own-produced food, although this figure is underestimated as it only includes plant-based food. More than 80% of the households can access a market within 60 minutes from their homestead. Finally, more than a quarter of households are in the lowest quintile of per-capita food expenditure.

Table 3: Summary Statistics (national average)

Variable	Mean	Median	SD	Min	Max
Household level					
Household size	6.85	6	4.04	1	23
Household head age	46.14	44	15.42	15	99
Female household head	13.95%				
Household head education					
None	75.22%				
Primary	13.94%				
Above primary	75.22%				
Urban	27.92%				
Household total land ownership	2.4	1.5	2.88	0	18.5
Production level					
Number of food groups produced[a]	1.24	1	0.96	0	4
Number of food items produced	2.26	2	1.97	0	10
Household produces vegetables	6.00%				
Total production quantity	278.9	200	361.53	0	2500
Assets and income					
Number of different kinds of durable goods[b]	4.65	4	3.65	0	22
Household off farm income	28916	0	179453	0	6000300
Proportion of consumption from own production[d]	31.54	31.04	28.39	0	100
Food expenditure (per capita at the household)					
Quintile 1	25%				
Quintile 2	21%				
Quintile 3	20%				
Quintile 4	18%				
Quintile 5	16%				
Nearest Market					
is 0 - 14 minutes	37%				
is 15 - 29 minutes	22%				
is 30 - 44 minutes	16%				
is 45 - 59 minutes	8%				
is 60 minutes or more	18%				
Biophysical (2000-2013)					
Mean temperature (C)	28.63	28.75	0.6	27.16	30.95
CV temperature	0.09	0.09	0.01	0.08	0.13
Mean precipitation (mm^3)	36.71	33.86	14.24	11.06	69.66
CV precipitation	1.31	1.3	0.17	0.89	1.68

[a]: Production food groups are defined as follows: (1) cereals, (2) roots, tubers and plantains, (3) pulses, legumes, nuts and seeds, (4) vegetables, (5) fruits, (6) meat, (7) fish and seafood, (8) milk and dairy products, (9) eggs, (10) oils and fats, (11) beverages, (12) miscellaneous. The EMC did not collect data for livestock holdings, therefore, we only have production information for food groups (1) – (5) and (12). The production items were categorized into these groups in line with Swindale & Bilinsky (2006).
[b]: Durables include cars, motorcycles, cycles, radios, television, air conditioning, refrigerator, etc.
[c]: Agricultural equipment include rice thresher, ploughs, carts, milling machine, seeder, etc.
[d]: Based on consumption in the last 7 days
Note: Results have been weighted by survey sampling weights. For education level, having no education has been combined with preschool education level.

Table 4 shows average HDDS to be approximately 7, while the Berry Index and HFDI are on average 0.59 and 0.15, respectively. The minimum of zero of the Berry Index is associated to households reporting the consumption of just one food item[6], food items for which unit information is missing (*feuilles -oseilles, baobab, boulvaka-* and *beurre de karité*), or food items for which edible quantity factor is missing in the West Africa Food Consumption Table (*kapok -voaga-*). Consequently, the HFDI -a product of the household Berry Index and dietary health value- is also zero for the same households.

Commented [BA(1]: Clarified

Table 4: Summary statistics (outcome variables)

Outcome Variable	Mean	Median	Standard Deviation	Minimum	Maximum
HDDS	6.76	7.00	1.75	1.00	12.00
Berry Index	0.59	0.66	0.24	0.00	0.93
HFDI	0.15	0.17	0.06	0.00	0.28

Note: Results have been weighted by survey sampling weights.

Almost all households consumed cereals and vegetables while 80% reported consuming fish and seafood (Table 5). In contrast, only 16% consumed roots, tuber and plantains, 12% consumed fruit, and only 6% consumed eggs, something concerning given that these food groups are crucial for health, nutrition, and correct functioning of the human body (Kuang, Yang, Zhang, Wang, & Chen, 2018; Slavin & Lloyd, 2012).

[6] Beverages and miscellaneous are excluded from the index calculation.

Table 5: Food group consumption

No.	Food group	% of sample
1	Cereals Bread, corn flour, fonio, maize, maize flour, millet, millet flour, other cereal products, other cereals, pasta, rice, sorghum, sorghum flour	98
2	Roots, tubers, and plantains Cassava, potato, sweet potato, yam	16
3	Pulses, legumes, nuts, and seeds Beans, other nuts	51
4	Vegetables Greens, kapok (voaga), okra, onions, tomato paste, tomatoes	97
5	Fruits Includes pineapples, papayas and oranges. The household was only asked about fruit consumption; therefore, we do not have data regarding the individual consumption of these items.	12
6	Meats Beef, other meats, pork, poultry, sheep/goat	45
7	Fish and seafood Dried fish, fresh fish, smoked fish	80
8	Milk and dairy products Milk, milk products	20
9	Eggs	6
10	Oils and fats Oils, other oils/greases, peanut paste, shea butter	88
11	Beverages Beer, coffee, mineral water, soft drinks, traditional beer, wine and liquors	58
12	Miscellaneous Granulated sugar, seasoning cubes, sugar cubes, sumbala seasoning, tea, kola nuts	98

Note: Results have been weighted by survey sampling weights.

Figure 1 shows consumption across food groups based on the distance to the nearest market. While the relationship is not consistent across all food groups, we observe that being closer to the market(s) is positively associated with eggs, fruits, meats, and roots, tubers and plantains consumption, as expected.

From Table 6 we see that fruits and roots, tubers and plantains are produced by the smallest share of households, which automatically limits the amount that can be consumed through own-production. Another option to consume these food items is to purchase them from the market. As we saw above, they have relatively higher rates of consumption among households close to a market – thus providing some justification as to why market access seems to affect only certain food groups. Unfortunately, since the EMC did not collect data on production of animal sourced food (ASF), it is difficult to conclude that the same finding applies to eggs and meats as information on whether the household produces these items is unavailable in the EMC survey.

Figure 1: Food group consumption by market access

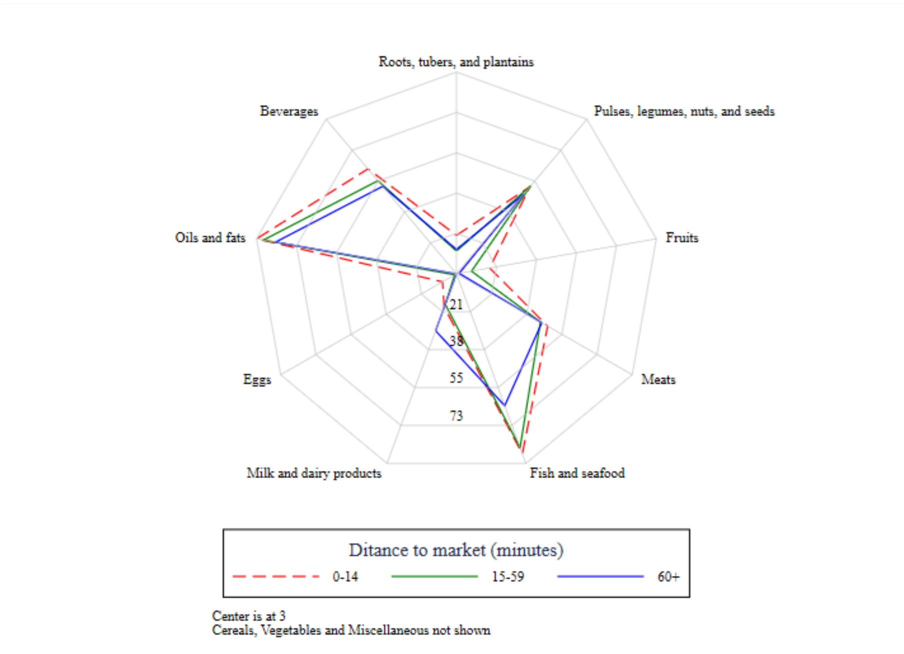


Table 6: Crop production

Food Group	Share of households (%)
Cereals	67.55
Roots, tubers and plantains	0.83
Pulses, legumes, nuts, and seeds	48.96
Vegetables	5.87
Fruits	0.20
Cash and Other crops	10.89
Non-Producers	31.37

Note: Figures have been weighted by sampling weights.

Although the Berry Index and HFDI embed an additional dimension over the HDDS, Table 7 confirms that these indicators are positively correlated. The HFDI and Berry Index are highly correlated because by construction the HFDI is built on top of the Berry Index. However, we observe that the HDDS and HFDI have a lower level of correlation. This suggests that the straightforward increase in the number of food groups consumed does not necessarily translate into a better diet -the added food group must be consumed in an adequate quantity and should provide a substantial nutritional value.

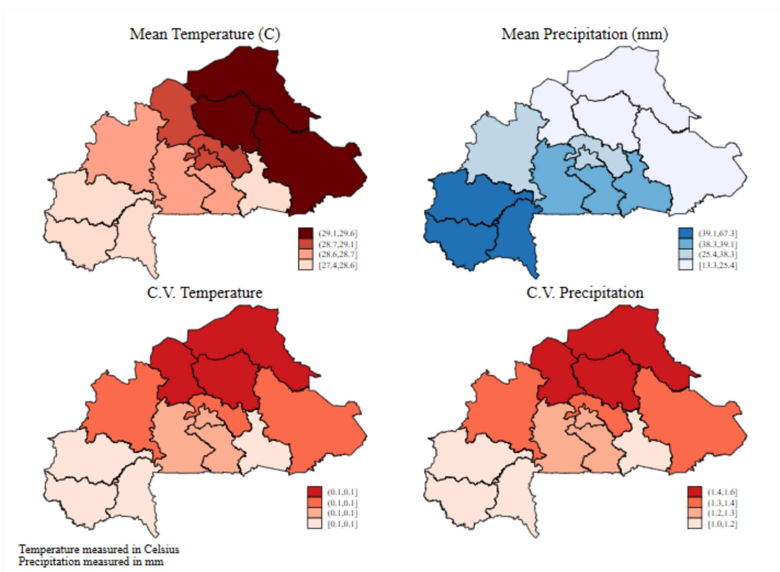
Table 7: Correlation between the measures of diversity

Measure	HDDS	Berry Index	HFDI
HDDS	1		
Berry Index	0.58	1	
HFDI	0.41	0.87	1

Note: Pair-wise correlations are all significant at the 1% level

Figure 2 shows the regional variation of selected biophysical characteristics between 2000 and 2013.

Figure 2: Regional variation of biophysical factors (2000-2013) (monthly averages)



The northern regions of the country on average exhibit the hottest weather, but also the highest variation in temperature. Precipitation is highest in the southwest-western region of the country. Although the northern and eastern regions of the country exhibit the driest weather (lowest precipitation), they also exhibit the largest variation in precipitation. In contrast, the southwestern region of the country shows the highest amount of precipitation jointly with the lowest variation in precipitation.

Figure 3 shows that the central regions of the country -except for the capital region of Ouagadougou- exhibit the highest food item production diversity while the northern and western regions show the lowest diversity. Looking at our outcome variables (HDDS, Berry Index and Healthy Food Diversity index) based on consumption, we notice that northern and eastern regions of the country show the lowest dietary diversity -and quality- with the western region exhibiting the highest. While we do not see a clear positive relationship between production and consumption diversity, the three measures of consumption diversity trail each other quite closely.

These findings need to be interpreted with caution given the lack of ASF production data and the consequent underestimation of the food item production diversity. This problem is exacerbated in the northern region of the country (the Sahel) where land is of poor quality, forcing most households to be pastoralists (Fleury, 2006), with the highest expected milk production in the region. While milk production figures cannot be confirmed due to data limitations, Figure 4 (in the appendix) highlights that the Sahel has the highest share of milk consumption in the country.

Figure 3: Regional variation of production and consumption

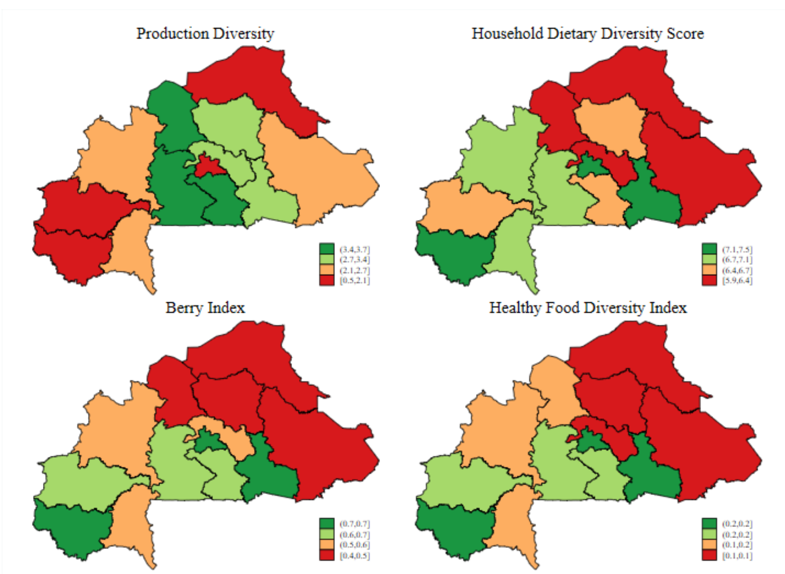


Table 8 highlights the positive relation between living in urban areas, education levels, and diet quality across our outcome variables of interest.

Table 8: Outcome variables statistics by socio-demographic characteristics

Parameter	HDDS	Berry Index	HFDI
Urban	7.2	0.75	0.17
Rural	6.59	0.53	0.14
Sex of household head			
Male	6.76	0.59	0.15
Female	6.73	0.6	0.15
Education level of household head			
None	6.55	0.55	0.15
Primary	7.72	0.77	0.17
Above primary	7.2	0.75	0.17

Note: Results have been weighted using survey sampling weights.

We specify two regression models for each outcome indicator (Table 9). Model (1) includes socio-demo-economic variables, such as household size, urbanization indicator, sex, age and education of household head, wealth (number of durables owned, number of agricultural equipment owned), travel time to market (as *proxy* of market access) and region fixed-effects. In model (2), plausibly exogenous biophysical controls that could potentially affect agricultural production are added. These controls include temperature and precipitation data both in the 2013 cropping season and between 2000 and 2013.

Living in urban areas is positively and significantly correlated to HFDI. Interestingly, the direction of the correlation changes when the HDDS as opposed to the HFDI and Berry Index are used. However, the absolute magnitude of the parameter -0.02 for model (2) is quite small and translates into a reduction in HDDS by <1%.

Female-headed households are associated with improved dietary outcomes when the HDDS, the food count index and Berry Index are used, while the correlation is ambiguous when the HFDI is utilized as the left-hand side variable. While we are unable to draw conclusive results on the basis of the HFDI, the positive association based on our other indicators support previous findings according to which empowering women lead to better dietary outcomes (Amugsi, Lartey, Kimani, & Mberu, 2016; Malapit, Kadiyala, Quisumbing, Cunningham, & Tyagi, 2015).

Compared to households whose heads are illiterate, those headed by an individual with primary education seem to show a higher dietary diversity and quality, as witnessed by the positive and statistically significant correlation with the HFDI, Berry Index, and the Food Count Index. Education level above primary is positively and significantly correlated with the HDDS and Berry Index, although surprisingly not with the HFDI. In addition to human capital, also physical capital -measured by the distinct number of durables owned- is also positively associated with diet quality across each indicator and model.

Production diversity -expressed as the number of unique crops produced- is positively correlated to the HDDS corroborating previous studies (Jones, 2016; Jones et al., 2014; Koppmair et al., 2017; Snapp & Fisher, 2014), the Food Count Index, and the HFDI, while correlation is ambiguous when the Berry Index is used. Interestingly, over the national sample the number of agricultural equipment owned does not seem to correlate with any measures of dietary quality.

Our study is limited by the lack of data on livestock ownership and rearing. Given the regional variation in climatic factors, this shortcoming limits our knowledge on production activities households are engaged in depending on their location. Indeed, in certain parts of the country pastoralist livelihood is more likely due to weather and soil conditions, being also linked to ASF production not captured in our estimates.

The association between market access and diet quality is in general positive when parameters are statistically significant -relative to the reference category of living within 14 minutes travel time from a market-, in line with previous analyses (Jones, 2016; Jones et al., 2014; Koppmair et al., 2017; Snapp & Fisher, 2014).

We observe a negative correlation of rainfall level and variation during the cropping season for the HDDS. Mean monthly temperature during the cropping season is negatively correlated with HDDS, but positively correlated with the HFDI. On the opposite, temperature variation is positively correlated with the HDDS and Food Count Index, while it is not significant for the Berry Index and HFDI. Average monthly temperature during 2000-2013 shows a negative relationship with the HFDI, while the association with the HDDS, Food Count Index and Berry Index are not significant. 2000-2013 temperature variation is associated with a negative correlation with the Food Count Index, but the effect on our other indicators is ambiguous.

Table 9: Regression estimates

	HDDS		Food Count Index		Berry Index		Healthy Food Diversity Index (HFDI)	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Household size	0.00156**	0.00164**	0.00571***	0.00590***	-0.00217***	-0.00194***	0.000267	0.000355*
	[2.01]	[2.13]	[5.78]	[5.96]	[-3.03]	[-2.72]	[1.35]	[1.81]
Urban	-0.0180**	-0.0201**	0.0114	0.00904	0.0727***	0.0722***	0.0108***	0.0108***
	[-2.04]	[-2.27]	[1.00]	[0.80]	[8.94]	[8.87]	[5.55]	[5.53]
Female head	0.0485***	0.0477***	0.0594***	0.0581***	0.0159**	0.0142*	0.000751	0.000185
	[5.27]	[5.22]	[5.02]	[4.98]	[1.97]	[1.80]	[0.35]	[0.09]
Head age	0.000117	0.000104	0.000162	0.000145	-0.000798***	-0.000777***	-0.0000703	-0.0000663
	[0.60]	[0.53]	[0.67]	[0.61]	[-4.47]	[-4.42]	[-1.50]	[-1.44]
Head education*								
Primary	0.0168	0.0163	0.0327***	0.0324***	0.0320***	0.0319***	0.00620***	0.00622***
	[1.64]	[1.59]	[2.87]	[2.86]	[4.54]	[4.57]	[3.42]	[3.46]
Above primary	0.0307**	0.0317**	-0.0255	-0.0233	0.0128	0.0141*	-0.00783***	-0.00743***
	[2.12]	[2.20]	[-1.52]	[-1.38]	[1.51]	[1.69]	[-3.63]	[-3.46]
No. of durables owned	0.0316***	0.0314***	0.0371***	0.0367***	0.0201***	0.0200***	0.00347***	0.00342***
	[26.02]	[25.82]	[24.20]	[23.84]	[18.89]	[18.72]	[14.36]	[14.07]
No. of food items produced	0.0136***	0.0136***	0.0165***	0.0162***	0.00129	0.00224	0.00104*	0.00125**
	[6.17]	[6.13]	[5.78]	[5.72]	[0.61]	[1.09]	[1.92]	[2.35]
No. of agri equipment owned	0.000697	0.000453	-0.000596	-0.000613	-0.000714	-0.00153	0.0000199	-0.000213
	[0.34]	[0.22]	[-0.21]	[-0.22]	[-0.35]	[-0.78]	[0.04]	[-0.40]
Nearest market (in mins)#								
15 – 29	-0.0196**	-0.0195**	-0.0138	-0.0144	-0.0246***	-0.0238***	-0.00271	-0.00259
	[-2.01]	[-2.02]	[-1.12]	[-1.18]	[-3.52]	[-3.47]	[-1.44]	[-1.40]
30-44	0.00309	0.00129	0.0106	0.00870	-0.00710	-0.00587	0.000761	0.00122
	[0.29]	[0.12]	[0.84]	[0.69]	[-0.85]	[-0.71]	[0.35]	[0.58]
44-59	0.0160	0.0127	0.00324	0.000448	-0.00364	-0.00289	0.00115	0.00175
	[1.37]	[1.10]	[0.22]	[0.03]	[-0.34]	[-0.28]	[0.40]	[0.63]
60+	0.00767	0.00521	-0.0197	-0.0187	-0.0228**	-0.0210**	-0.00637**	-0.00501*
	[0.71]	[0.48]	[-1.40]	[-1.32]	[-2.20]	[-2.03]	[-2.36]	[-1.85]
2013 Cropping season								
Mean monthly precipitation		-0.00978**		-0.00521		-0.000716		0.00147
		[-2.37]		[-0.92]		[-0.15]		[1.26]
C.V. monthly precipitation		-0.398***		-0.162		0.0674		0.0436
		[-3.10]		[-0.91]		[0.37]		[1.04]
Mean monthly temperature		-0.325***		-0.0454		0.0691		0.0750**
		[-2.75]		[-0.27]		[0.51]		[2.43]
C.V. monthly temperature		6.780*		10.31**		-0.850		-0.899
		[1.92]		[2.24]		[-0.22]		[-0.90]
2000-2013								
Mean monthly precipitation		0.00298		-0.00213		-0.000838		-0.00200
		[0.59]		[-0.30]		[-0.14]		[-1.32]
C.V. monthly precipitation		-0.0168		-0.0465		-0.176		-0.0303
		[-0.07]		[-0.13]		[-0.52]		[-0.34]
Mean monthly temperature		0.161		-0.153		-0.0841		-0.0709***
		[1.59]		[-1.10]		[-0.73]		[-2.76]
C.V. monthly temperature		-3.393		-14.77**		-3.019		-1.516
		[-0.69]		[-2.25]		[-0.54]		[-1.10]
Constant	1.662***	6.849***		9.369***	0.555***	1.564	0.142***	0.259
	[89.36]	[5.09]		[5.08]	[39.33]	[0.99]	[39.70]	[0.63]
Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Biophysical var	No	Yes	No	Yes	No	Yes	No	Yes
R-Square	-	-	-	-	0.349	0.355	0.178	0.185
Observations	10692	10692	10692	10692	10631	10631	10631	10631

t-statistics in brackets. * p < 0.1, ** p < 0.05, *** p < 0.01. Robust standard errors clustered at the enumeration area. Poisson model for HDDS and Food Count; OLS for the Berry Index and HFDI. Estimates are weighted, taking sampling design into account. *: No education combined with preschool is the base comparison group – not shown. #: Market between 0 and 14 minutes is the base comparison group – not shown.

6 Conclusions

The personal and societal costs of macro and micronutrient deficiencies are quite high, and several policy options are being pursued to tackle this inadequacy including several nutrition-sensitive interventions and nutrition-specific investments. For example, one policy option is the diversification of production, away from grain staples and towards more nutritionally dense meats, nuts, and vegetables. In many developing countries, both production and consumption are heavily dependent on cereals in which production is insufficient to meet domestic caloric needs. While nutritional composition of these staples may vary depending on the variety, they generally lack crucial micronutrients such as vitamins A, C, and B12, and bioavailability may be limited for some of the B-vitamins and minerals they contain (e.g., B6, iron, zinc). Food items such as tomatoes, leafy greens, fruits and animal source foods can help address both caloric and micronutrient deficiencies, as would biofortification of cereals.

Through this study, we are able to confirm previous research findings on the determinants of a balanced household diet in Burkina Faso. Furthermore, we contribute to the existing literature by experimenting with the use of two low frequently used dietary diversity indicators: the Berry Index and the Healthy Food Diversity Index. While we are confident that the HFDI is a considerable improvement over the HDDS, results based on HFDI should be interpreted with caution due to lack of national dietary recommendations for Burkina Faso. In the absence of this vital information, we use the 75^{th} consumption percentile of self-reported consumption from women from only two districts of the nation's capital, Ouagadougou. This limitation could potentially bias the final recommended consumption set based on food categories. Given that we make use of food category proportions to assign health values to different food groups, it would be important to recalibrate the data analysis of this study when local dietary quantity recommendations become available. Additionally, we are also unable to accurately capture the correlation between consumption and production diversity as the EMC did not include data on production of animal sourced foods.

Burkina Faso's *Plan stratégique intégré de lutte contre les maladies non transmissibles* does not mention any specific strategy to promote a balanced diet. Overall, there is no targeted effort taking place that aims at improving access of the population to a balanced diet. In the absence of local interventions, our findings could potentially inform policy making by identifying possible avenues that might maximize nutritional benefits. Given that urban residents report relatively more balanced diets, concerted effort to improve availability and accessibility of food in rural Burkina Faso should be sought. The latter objective may be achieved through strategic support to production diversity in general and production of animal-source foods in particular, especially in regions with conducive climatic conditions, through supporting measures such as expansion of irrigation infrastructure. Given that travel time to the nearest market is negatively associated with balanced diet, investments on roads and transportation can create opportunities for consumers and communities who cannot otherwise only rely on their own-, sub-optimal production due to limited physical access to input and output markets. The positive association between female headship and balanced diet may point us towards the benefits of interventions aimed at empowering and informing women, including on intra-household decision making and good cooking, nutrition, and feeding practices.

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Appendix

Figure 4: Milk consumption in the population (%), by region