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Rural household welfare in Papua New Guinea: food security and nutrition challenges

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ABSTRACT

Papua New Guinea continues to encourage a policy focus on food and nutrition security. The PNG National Nutrition Policy (2016-2026) and Nutrition Strategic Action Plan (2018-2022) (NSAP) set a path to improve coordination, secure sufficient funding, and improve technical capacity of nutrition-focused program implementation.

As policy prioritizes improved nutrition outcomes, it is important to understand the cost that households face of securing a higher level of nutrition. Ensuring a healthy diet that meets nutrition standards is relatively expensive in PNG. The analysis presented in this paper, which uses detailed household food and non-food consumption data suggests that 4/5 of households in the survey sample live below the healthy diet poverty line (which sets a calorie threshold and defines healthy diet nutrition targets). That is, these households do not have the income available (or do not consume sufficient food and non-food goods) to meet their basic needs which includes securing a nutritious diet that meets food based dietary guidelines.

We highlight three interventions that should be prioritized based on the nutritious poverty line results presented in this paper. First, PNG will continue to face disruptive climate events that quickly increase agricultural vulnerability and food insecurity in remote areas with limited market access and underdeveloped support services. The government of PNG in collaboration with development partners should begin to pilot social safety net programs that can provide support to vulnerable populations. A well-maintained social safety net has positive externalities beyond merely food consumption support. Recent research evaluating impact of income support programs during Covid-19 demonstrated that countries with an established safety net mechanism were more efficient and effective at delivering necessary supplies and support to vulnerable populations (Gilligan, 2020). For PNG, a safety net program should focus on food and nutrition security, in tandem.

Second, a concerted effort is needed to better promote the importance of nutrition in food consumption choices. Capacity strengthening is needed at all levels. At the household level, training should aim to instill (for both men and women) the value of a costlier, but more nutritious diet. District and regional government officials, healthcare workers and other key stakeholders should receive training on the importance of improved nutrition for greater economic growth and human development targets. While dialogue should focus on nutrition objectives, economic constraints and affordability of nutritious diets must be a part of the conversation. High-level government dialogue and learning should aim to encourage greater coordination between local and federal government officials and across government departments to ensure nutrition objectives are integrated into development planning.

Finally, PNG must invest in more timely data collection of key welfare indicators. These indicators should be designed in consultation with trained nutritionists and government stakeholders responsible for financing and reporting on the delivery of essential nutrition services and programs. This study uses the most recent data to estimate a cost of a nutritious diet. In doing so, it can support policy and aid investments (e.g., social safety net transfers, child nutrition interventions, and benefit-cost assessments of food and nutrition assistance composition) to assess the equivalent cost that a rural household faces to secure a healthy diet. It also sets a benchmark for understanding poverty prevalence that accounts for the cost of achieving other development objectives of reducing child undernutrition and improving development targets linked to improved nutrition (e.g., improved school attendance, increased labor productivity and higher wage earnings).

INTRODUCTION

While food insecurity in Papua New Guinea remains a challenge to the country's development trajectory, lack of dietary diversity is also exacting a heavy cost on both rural and urban populations. The most recent government-endorsed nutrition policy published in 2016 highlighted an ongoing concern of PNG's stagnant and high child stunting rates (44 percent of children under 5 years of age). The 2016 PNG Nutrition Policy identifies inadequate food, health and care as primary drivers affecting nutrition outcomes from birth through adulthood. Other key PNG policy documents (PNG National Human Development Report, 2014; PNG Infant young child feeding policy, 2016) have echoed the importance of better assessing the gaps and challenges in ensuring healthy diets to PNG rural and urban households. PNG is not alone in identifying poor nutrition as an important development challenge. About 9 percent (689 million) of the global population lives under the international poverty line (1.90 USD per day) (World Bank, 2022), however it is thought that approximately 25 percent (2 billion people) suffer from micronutrient deficiencies.

In addition to the use of the international poverty line, poverty prevalence in low- and middle-income countries (LMICs) is also analyzed by estimating national poverty lines that represent the cost of attaining a basic welfare level within a given country. The poverty line is defined in terms of consumable food goods (or the food basket), which comprise a majority share of the cost of achieving a basic welfare level, with a smaller share dedicated to non-food goods (for basic items such as such as soap, clothes, transport, shelter, etc.)

The cost of basic needs approach defines a basic level of welfare as one that allows individuals to lead a healthy and active life and to achieve social inclusion (Ravallion, 1998). Thus, food baskets are intentionally selected to reflect the consumption choices of the poor and near poor while also adhering to a specified nutrition standard. Conventionally, the nutrition standard is defined as a calorie intake threshold, which omits other important food nutrition requirements. However, poorer households often seek to meet caloric needs first, which tend to be foods that are cheap sources of energy (calories) but often lack diversity, as well as important micronutrients and high-quality proteins and fats (Subramanian and Deaton, 1996; Headey and Alderman, 2019). As a result, aligning the food consumption patterns of poor households to a calorie threshold alone likely leads to a food poverty basket that is nutritionally inadequate and overlooks the increasingly urgent concern of widespread under (and over) nutrition occurring across many LMICs, including PNG.

Recent literature in PNG has analyzed poverty prevalence using the conventional cost of basic needs poverty line approach (Schmidt et al., 2020; World Food Program, 2018; Gibson, 2012). However, given the intransigent child stunting rates that remain across the country, further work is needed to evaluate the cost of a food basket that not only meets calorie requirements, but also ensures a nutritionally balanced diet that supports healthy growth and wellbeing. This paper begins to fill this gap by analyzing recently collected consumption and expenditure data from a 2018 rural household survey paired with detailed food price information. In doing so, we calculate the cost of two food baskets with different nutritional standards: 1) cost of basic needs, energy-based food basket which aligns with energy requirements; and 2) cost of a healthy diet food basket which aims to meet energy *and* healthy diet objectives (demonstrated by Mahrt et al., 2022; Herforth et al., 2020). The cost of the energy-based and healthy diet food baskets together with a non-food allowance, yields energy-based and healthy diet poverty lines. Comparing the healthy diet poverty line to household income suggests that attaining a nutritious, balanced diet while meeting other basic needs remains out of reach for nearly 4/5 of the rural sample households. While increasing nutritional knowledge and awareness is an important component to improving dietary diversity among rural households, further agricultural production enhancing and

diversification investments, as well as improved transport and marketing infrastructure is necessary to support greater access to more nutrient rich foods.

The remainder of the paper is organized as such: the following section reviews the literature evaluating the cost implications of a healthy diet and associated poverty measurements. In doing so, we assess current nutrition indicators and challenges specifically related to PNG, recognizing that undernutrition prevalence is associated with a variety of factors beyond economic (price and income) drivers. Section 3 describes the data and methodology used to calculate and compare different costs of diets (both energy-based diet and healthy diet), and also explains the methods used to calculate sample area specific poverty lines and poverty prevalence. Section 4 discusses results of the analysis, comparing the costs and associated poverty prevalence differences between the energy-based food poverty line and the healthy diet food poverty line. Section 5 concludes.

BACKGROUND AND LITERATURE REVIEW

A growing body of research suggests that consumption of sufficient, nutrient-rich foods is associated with lower stunting rates among children (Headey et al., 2018; Darmon, 2015; Arimond and Ruel, 2004; Headey, Hirvonen, and Hoddinott, 2018; Ruel, Quisumbing, and Balagamwala, 2018). Black et al. (2013) demonstrate that achieving improved child nutrition is associated with decreased vulnerability to infectious disease and avoidable physical and mental disability. In addition, well-nourished and healthy children are more likely to achieve greater educational attainment in youth, and relatedly greater income generation in adulthood (Hoddinott et al., 2013).

Undernutrition incidence in PNG is shaped by a complex set of factors that echo other global and diverse country case-studies. Consumption trends differ by household income (Schmidt et al., 2019; Pham et al., 2021; NSO – Demographic and Health Survey, 2016-18; Gibson, 2012), access to markets / remoteness (Rogers, 2011; Miyoshi et al., 2015), disease prevalence including diseases related to water, sanitation and hygiene practices (Hall et al., 2020), societal and cultural influences on food preferences (Hurney, 2017; Pham et al., 2021) and environmental and geographic characteristics (Bourke and Harwood, 2012). All of these factors will require a mix of economic policy, agricultural financing mechanisms, nutrition education investments and healthcare interventions.

Country-specific studies have evaluated the effects of supplementing child diets with a greater variety of foods, particularly foods rich in protein, to improve targeted nutrition outcomes.[1] For example, Iannotti et al. (2017) conducted a randomized control trial that provided children 6-9 months of age one egg per day for a 6-month period. Compared to children in the control group (that didn't receive an egg daily), stunting prevalence for those children who were provided an egg decreased by 47 percent relative to the control group. A small pilot study in West Java province, Indonesia supplemented child (36-60 months) diets with eel biscuits, resulting in modest improved height-for-age z scores (compared to the control group) after 3 months of intervention (Herawati, 2020). A cluster-randomized controlled trial

[1] Impacts of improved nutrition in older age cohorts also demonstrates significantly positive outcomes, including: improved birth weight among adolescent mothers (Rehana et al., 2016); improved blood glucose control in late middle-aged adults with type 2 diabetes (Li et al., 2016); improved immune function in elderly populations (Lesourd and Mazari, 1999).

in rural Bangladesh tested the effectiveness of fortified complementary food supplementation introduced to 6-month old children for 1 year.[2] Results suggest that nutrition counseling and small amounts of daily fortified complementary foods increased linear growth and reduced stunting rates measured at 18 months (Christian et al., 2015). Tang et al. (2014) conducted an experiment in rural China that provided a daily ration of either minced pork (treatment) or rice (control) to children aged 6-18 months for 1 year. Children that were provided a daily ration of pork experienced a modestly greater linear growth compared to the control group.

While strong evidence demonstrates the benefits of investing in nutritious diets, especially among child-bearing women and young children, studies across the globe have identified important barriers to achieving improved nutrition outcomes. Nutrition economists have highlighted that food preference and taste can shape consumption decisions and are formed by family and food consumption practices at home that make up longer-term habits (Benton, 2004; Masters et al., 2018; Binkley and Golub, 2011). It takes only a moment to think of a 'comfort food' that is less healthy but holds meaningful importance in a personal diet.

Previous studies also show that less healthy diets can be associated with a lack of context-specific food and nutrition information (Dewey and Adu-Afarwuah, 2008; Menon et al. 2015; Leroy and Frongillo, 2007). This lack of knowledge can be interwoven with food taboos that shape consumption practices and preference (Zerfu, Umeta, and Baye, 2016; MacDonald, 2000). For example, dietary rules and regulations for pregnant and lactating women in areas of PNG strongly suggest against consuming foods high in protein (Meyer-Rochow, 2009). Gender bias and low levels of maternal empowerment are also widely cited constraints to achieving nutritious diet targets (Jayachandran and Pandi, 2017; Hadley et al., 2008; Dancer et al., 2008).

Household income and associated food prices are also an important determinant of household food consumption choices and nutrition outcomes, both of own-production and purchased food items. Many studies have demonstrated Bennett's law, whereby as household income increases, diets shift from predominantly starchy staple foods to comparatively more expensive food items such as fruits, vegetables, dairy and animal source foods (Timmer, 1983; Headey et al., 2018). Price differences of nutritious versus staple foods particularly affect poor households that dedicate a larger share of total household income to food consumption and expenditure (Green et al., 2013; Miller et al., 2016; Pingali, 2015). In Vietnam, Hoang (2018) has shown how increases in food prices result in greater expenditures on rice rather than other nutrient-dense foods. Brinkman et al. (2009) and Chang et al. (2016) have shown how higher food prices are associated with food insecurity and lower dietary quality.

To date, there has been little empirical work that calculates and compares the cost of a (locally available) recommended nutritious diet with the average household income of rural families in PNG. [3] While previous literature has argued that rural agriculture practices in PNG provide the needed caloric content for rural households, there is no empirical evidence that clearly demonstrates that rural households in PNG have the resources to acquire a diet consistent with nutrition guidelines that ensure a healthy diet. Conversely, there is growing global recognition that subsistence farming (or a heavy reliance on own production) is just not sufficient to satisfy micronutrient intake thresholds. Rather, food

[2] Participants (N=5,536) were divided into 3 treatment groups that received nutrition counseling and a different fortified food supplement (chickpea and rice-lentil based supplement; a fortified blended food of wheat-soy-blend++, WSB++; and Plumpy'doz supplement) and 1 control group (received only nutrition counseling).

[3] In the context of lower- and middle-income countries, income is measured using consumption-expenditure. Consumption-expenditure encompasses the value of all food and non-food items consumed or used by the household including foods and other goods received in-kind or produced by the household.

markets are crucial to supporting nutrient-rich, non-staple food consumption among rural populations (Headey et al., 2019).

Ensuring a healthy diet in PNG is relatively expensive, and our results suggest that the majority of households in the survey sample live below the healthy diet poverty line (which sets a calorie threshold and defines healthy diet nutrition targets). That is, these households do not have the income available to meet their basic needs which includes securing a nutritious diet that accounts for food availability, preferences, and current food prices. In short, an important share of the rural households in the sample do not have the income available to meet a calorie adequate basic food basket while also meeting other basic non-food needs. An even larger share of the rural household sample lacks the economic resources to acquire a calorie adequate basic food basket that also ensures a healthy, nutritionally balanced diet while also meeting other basic needs.

DATA AND METHODOLOGY

We use recent consumption and expenditure data collected during 2018 to estimate total daily household income. However, a challenge arises when calculating total household income in LMICs because it is difficult to attach a monetary income or wage value to subsistence agricultural and informal or seasonal labor. For example, while households engaged in subsistence farming work in their gardens to produce food to eat (which, intrinsically, has the same value as income a household earns to buy the same food) and/or sell food to supplement own-produced food consumption, it would be difficult for a household to estimate an annual wage or income from such an activity. Thus, to better approximate total household income within this environment, economists use detailed food and non-food consumption and expenditure data from household surveys to calculate a total household consumption-expenditure value.[4]

The food poverty line is the cost of a basket of *food* goods that is consistent with consumption patterns in poor households and meets a defined nutrition standard. For this study, we define two food poverty lines: 1) the energy-based food poverty line (which only targets a calorie threshold) and 2) the healthy diet food poverty line (which targets a calorie threshold *and* a more comprehensive healthy diet standard). Calculating the energy-based food poverty line requires two key pieces of information: 1) household food item consumption quantities and 2) food item prices, both of which are attained from household survey data. The healthy diet food poverty line requires a third piece of information which is a dietary guideline (described in more detail below) that suggests a quantified recommended diet of specific food groups that meets a set of caloric, health and nutrition outcomes. The following discussion provides further detail on the data and methodology employed to calculate the different food poverty lines and associated food baskets. In addition, we describe the calculation of the total poverty line, which incorporates the two food poverty lines described above and a non-food allowance informed by the household survey expenditure data. Total estimated household income is measured against the total poverty line value to assess whether households are able to meet the cost of living defined by the poverty line. Individuals in households that have a total expenditure greater than the poverty line are

[4] For the analysis presented here, we do not include long-lived items such as automobiles, appliances and furniture that would require a durable use value. Similarly, we do not include rental values. While we recognize that these items have a significant effect on living standard, the survey data lacked sufficient detail to include a comprehensive assessment of these expenditures in the poverty line assessment.

considered non-poor (or able to economically meet the minimum required welfare level), whereas individuals in households with a total expenditure less than the poverty line are considered poor.

Household food consumption-expenditure

We use detailed food consumption data from the 2018 PNG Rural Survey on Food Systems (RSFS) to evaluate current household dietary trends given that the nationally representative data on household food consumption is more than a decade old (2009/10 Household Income Expenditure Survey (HIES)).[5] The RSFS was implemented in four rural, lowland areas of PNG – East Sepik (Maprik, Wosera-Gawi and Yangoro-Saussia districts), West Sepik (Nuku district), and Madang (Middle Ramu and Usino Bundi districts) provinces and the Autonomous Region of Bougainville (Buin and Siwai area of South Bougainville). The survey comprised of 1,026 households in 70 communities, whereby respondents were asked to report household consumption of 40 different food items during the previous week.[6]

The survey asked respondents to report the quantity of each food item that the household consumed during the previous week; its source (own-produced, purchased, or received as a gift); and the amount paid for purchased items. We calculate food unit values based on the reported quantity and associated expenditure (when purchased) of each food item in the consumption module. To ensure reliable unit values at the most disaggregated level, we first calculate unit values from food items with at least 10 observations of purchased data at the lowest administrative level (Appendix Table A1 reports the number and share of unit value observations that are derived at each geographic level within the survey). However, unit value data of certain subsistence food items (e.g., sweet potato, sago and yam are predominantly consumed from the households' own gardens) lack a sufficient number of purchased unit value observations (collected during the RSFS 2018) to ensure reliable estimations. To estimate the unit values of these specific crops, we assign the average unit values from the 2009/10 HIES data (adjusted for food price inflation) at province level (Appendix Table A2 reports the data source for each food price used in the analysis). Finally, for specific vegetable and fruit items, we utilize 2018 price data collected by the Fresh Produce Development Agency in PNG which collects detailed fortnightly price data on fruits and vegetables.[7]

While the RSFS data are the most recent household consumption and expenditure data, the survey questionnaire asked about vegetable and fruit consumption using only four broad categories: dark green leafy vegetables, other vegetables, dark yellow or orange fruits, and other fresh fruits. Given that the healthy diet food poverty line and associated analysis evaluates the costs, calories, and nutrients of food items within defined food groups, a greater disaggregation of fruit and vegetable items is necessary. To address this issue, we use the Household Income Expenditure Survey 2009/10 (HIES 2009/10), which has a greater disaggregation of food items, to calculate the average quantity shares of each vegetable and fruit item consumed (in rural areas) within their respective food groups by province.[8] We then apply these consumption shares to the aggregate fruit and vegetable categories reported in the 2018 RSFS. The vegetable and fruit share of the total food basket (5.7 and 5.4 percent of

[5] Detailed information on the RSFS survey sample, stratification and selection can be found at Schmidt et al. (2019).

[6] After reviewing the data, 43 households were dropped from the analysis due to insufficient information on consumption and expenditure. The remainder of the paper is based on a sample of 983 households.

[7] The FPDA food price database can be downloaded here: https://www.ifpri.org/project/fresh-food-price-analysis-papua-new-guinea

[8] Given that we are interested in consumption profiles of average to poor households, we only include rural households in the bottom 3 income quintiles (bottom 60 percent of total household expenditure distribution).

expenditure, respectively) among rural households in the HIES 2009/10 dataset is similar to the RSFS 2018 share (4.3 and 6.6 percent, respectively).

Given that consumption-expenditure data is reported at household level, we calculate adult equivalency scales to facilitate comparison of household consumption-expenditure across different size households and differing household demographic composition. We compute equivalency scales for each member based on their age and sex-specific energy requirements relative to a reference age group (in this case we use the average for 30–49-year-old males and females).[9] Once we have accounted for household size and composition, we estimate the total expenditure and total quantity consumed of each food item per adult equivalent per day within each household. All food quantities and prices are calculated taking into account only the edible portion of each food item.

Food-based dietary guideline

Quantified food-based dietary guidelines

Food based dietary guidelines (FBDG) are national policy and education documents that frequently include quantified dietary recommendations. Recommended diets outlined in FBDGs are designed to meet the needs of a healthy population and describe a balanced and nutrient adequate diet that reflects local food availability and social and cultural food norms. Thus far, approximately 100 countries have developed an FBDG to support policy and programming for improved nutrition outcomes. PNG is yet to develop a country FBDG. However, Herforth et al. (2022) designed an internationally recognized healthy diet basket based on a variety of country FBDGs for the global affordability analysis. After reviewing the available FBDGs within the Asia Pacific region (including Indonesia, Fiji, Philippines, and Australia), we adopt (and adapt) the Indonesia FBDG because it best reflects the unique food items and consumption patterns in PNG. It also most closely resembles the food group categories and quantities proposed as the target measures for the global analysis by Herforth et al. (2022).[10]

The Indonesia FBDG organizes food items into food groups and a recommended daily consumption quantity for each food group to meet nutritional targets for specific age groups and gender cohorts. Although the main staples differ for Indonesia and PNG (e.g., rice for Indonesia and sago and sweet potato for PNG), the Indonesia recommended diet incorporates sago and sweet potato due to their importance in Papua and West Papua provinces (that border PNG). Other typical PNG foods are also described in the Indonesia FBDG such as fresh and tinned fish, aibika and other greens, and fresh fruits and vegetables (e.g., cucumber, cabbage, pumpkin, mango, and pineapple).

Using the guidelines reported in the Indonesia FBDG, we construct a PNG recommended diet table by introducing three modifications to the Indonesia recommendations. First, the Indonesian guidelines encourage consuming both animal source foods (ASFs) and pulses, which are both sources of protein and other essential nutrients. However, foods such as pulses, tofu, and tempeh were not identified as important food sources in PNG (and not specifically asked about in the HIES 2009/10 or the RSFS

[9] We adopt the daily caloric needs by sex and age described in Mahrt et al. (2019) for Myanmar given similarities in BMI, weight and height data reported for PNG (Benjamin et al., 2007).

[10] While the FBDG of Fiji and Philippines could provide more local consumption options for food groups, both guidelines provide only very general messages lacking specific quantity recommendations by food group. After evaluating the Australia FBDG, which provides more details on food group quantities, the consumption patterns vary more widely between Australia and PNG than the consumption patterns of Indonesia and PNG.

2018). Thus, for the modified PNG guidelines, we combine the pulse and ASF groups into a single protein-rich food group (which includes ASF and peanuts as important protein sources in PNG). In doing so, we set the suggested number of servings of protein-rich foods to reflect both ASFs and pulses based on the protein content of a reference food in the pulse food group (tempeh) relative to the ASF food group (fish).[11]

Second, the Indonesia recommended diet includes guidelines for sugar consumption to communicate upper bounds on sugar intake. Although foods such as soft drinks, sugar, and salt, are commonly consumed in PNG, we do not include sugars and other discretionary foods in the PNG diet (described in Table 1) given limited data. Therefore, the cost of these foods are also not included in the healthy diet food basket calculation.[12] Finally, the Indonesia guidelines recommend specific serving sizes and numbers of servings for several age groups by sex. For this analysis, we calculate a recommended diet for a reference adult aged 30-49 (Table 1).[13]

Table 1. PNG recommended diet adapted from Indonesia food based dietary guidelines, per adult (aged 30-49 years) per day

	Recommended number of servings	Serving size (grams)	Average recommended quantity (grams)
Staples	7.5	50	375
Vegetables	3.0	100	300
Fruits	5.0	50	250
Animal source foods	5.6	45	251
Oil	6	5	30

Source: Indonesia food-based dietary guidelines, and authors' calculations.

The dietary guidelines present serving sizes in terms of reference foods; however, the analysis presented in this paper is not restricted to only one food type per food group, but rather all foods listed in food consumption module of the survey that fall into the five recommended food groups. Thus, for each item, we calculate specific serving sizes based on a key nutrient provided by each food item relative to the reference food group item.[14] Using food item specific serving sizes, we calculate food group equivalent grams which allow comparison of food quantities within each food group.

[11] Based on the protein content in tempeh relative to fish, 3 servings of tempeh are converted to 2.6 servings of fish and added to the already recommended 3 servings of ASFs.

[12] These foods accounted for 7.3 percent of total food expenditure in the 2018 RSFS survey.

[13] When applied to PNG consumption patterns, the total energy of the Indonesia diet, excluding sugar, only provides 1,955 calories, which is much lower than the average energy required by 30–49-year-old adults in PNG (for this study 2,432 kcal). We increase the number of staple servings by 1.5 servings, which increases the energy of the diet to 2,218 calories. This energy level is more consistent with energy provided in the Indonesian recommended diet for 30–49-year-old adults, excluding sugar (2,275).

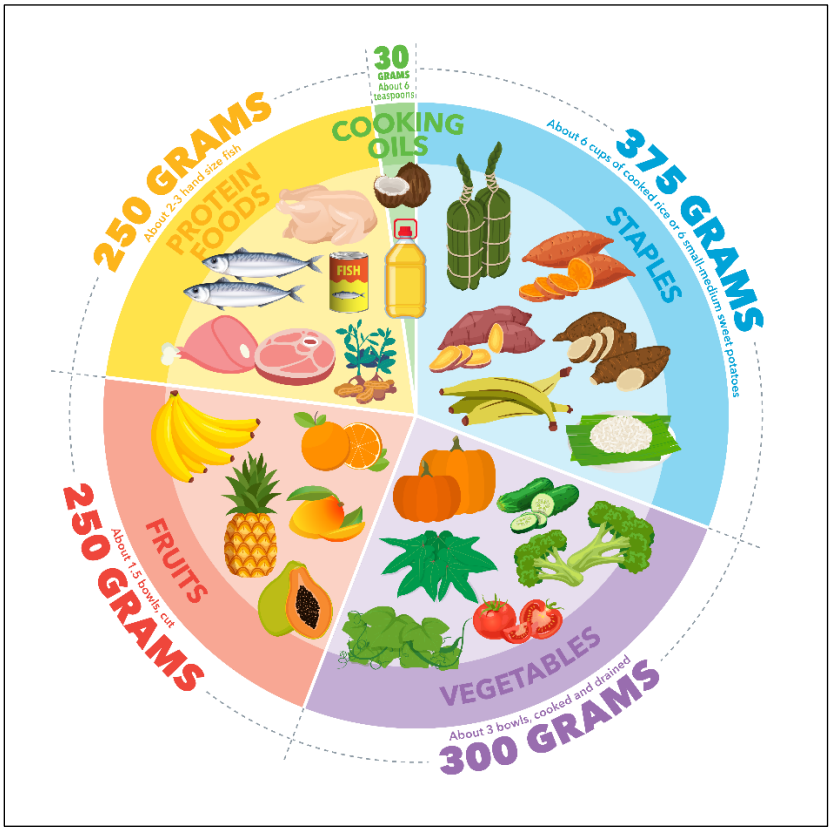
[14] We supplement reported data in the Indonesia food composition table (TKPI, 2019), with data from the SMILING project (Fahmida, 2013), Shaheen et al. (2013), Stadlmayr et al. (2012), USDA (2016) and WHO (1979). Nutrients including magnesium, vitamin B6, vitamin B12, folate, and vitamin A are not reported in Indonesia food composition table and are taken from USDA instead. Nutrients of rice, instant noodle, cooking banana, pork, game meat, tinned meat, tinned fish, bamboo shoot, cooking banana, peanuts, broccoli, all fruits, and margarine are from USDA, and pit-pit is from WHO.

Visualization of food-based dietary guidelines

Given that PNG has paid less attention to individual nutrition targets during the last several decades, the country lacks tools to communicate nutrition objectives in a visually understandable way. As an example, we include a food plate graphic (Figure 1) in this report to begin a conversation about what a healthy diet may consist of for local populations, however this figure is meant as a starting point rather than a defining output for nutrition policy in PNG. Local medical professionals and health and nutrition practitioners, as well as policy makers, should invest in an exercise to build a PNG specific FBDG considering local foods and agricultural practices and standard anthropometric measurements. This exercise should be accompanied with a set of visual education and communication tools (such as Figure 1), which would be a good first step towards integrating a nutrition lens to further economic, agriculture and health development and outreach programs.

A simple visualization of a recommended healthy diet that holds meaningful intake guidelines is frequently conveyed in terms of food volumes, thus the plate. However, for this exercise, we follow the recommended diet in Table 1 which is specified in terms of the gram weight of food items. Based on Table 1 visualized in Figure 1, an individual between 30-49 years of age should eat almost half of the total daily food consumption (grams) in fruits and vegetables. This is about the equivalent of 3 metric cups (small bowls) of cooked and drained vegetable (e.g., broccoli, carrot, cabbage, etc.) and 1.5 metric cups of cut fruit (e.g., mango, papaya, passion fruit, etc.) per day. Approximately one fifth of daily consumption (grams) should come from animal source foods or pulses, or about 2-3 hand-size portions of fish or palm-size portions of meat the thickness of a deck of cards.

Figure 1: PNG food nutrition plate based on adapted food based dietary guidelines



Note: Grams are specified in terms of raw edible portions for fruits, vegetables, and protein foods and in terms of dry rice for staples.

Source: Indonesia food-based dietary guidelines, and authors' calculations.

Given the gram weight and associated nutrient difference between starchy foods, it is difficult to prescribe an appropriate consumption amount across all populations in PNG. Foods within a food group can have significantly different energy or nutrient composition, and this is particularly true for starchy staple foods. For example, for Figure 1, we use dry rice as the food to visualize staple intake in grams, however in terms of carbohydrates, 50 grams of dry rice is equivalent to 177 grams of raw sweet potato. While for urban populations in PNG, rice is an appropriate food type to visualize daily food weight intake; sweet potato is more appropriate for rural consumption trends. Thus, recommended starch (and all other food items) consumption is dependent upon the food item. For PNG, this is equivalent to consuming about 5 metric cups of cooked rice or 6 small to medium (the size of a clenched fist) sweet potatoes per day.[15] For quantitative transparency, we have restricted our visual interpretation providing a single weight (e.g., recommended weight of daily rice intake). However, for the following healthy diet poverty line calculation based on reported food consumption, we convert every food item into food group equivalent grams and associated nutrient composition using the recommended diet and food composition tables.

Food basket cost and poverty estimation

We estimate an energy-based food poverty line that follows the traditional cost of basic needs approach to estimate the cost of an observed basket of foods consumed by reference poor households, which is then scaled to meet dietary calorie requirements (Ravallion, 1998; Ravallion and Sen, 1996; Wodon, 1997).[16] Arguably, a staple heavy diet, likely consumed by poor households, may not be consistent with the welfare standard of living a healthy life in that it would not be nutrient adequate. Thus, we also estimate the healthy diet food poverty line, which is a modification of the energy-based poverty line that meets a broader set of nutritional standards in addition to dietary energy (calorie) requirements (Mahrt et al. 2022).

Several considerations are required to identify the appropriate food items to include in both the energy-based and healthy diet food baskets. For the energy-based food basket we follow the approach outlined in Arndt and Mahrt (2017); and for the healthy diet food basket, we follow Mahrt et al. (2022). First, since we are interested in identifying appropriate modest food poverty lines, we restrict the household consumption data used to calculate the food poverty line to include only poor households. This reduces the influence of consumption choices of higher-income households, who are likely to consume more expensive food items.[17] The same reference poor households are used to calculate both the energy-based diet and the healthy diet food poverty lines.

Second, the healthy diet food basket is limited to foods that can be classified into healthy-diet food groups, which excludes foods like sugar cane, snack foods, tea, soft drinks, and alcohol. The survey

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[15] While this seems like a large amount of rice or sweet potato, this example (for brevity) assumes no other starch foods (e.g., other tubers, bread, grains, crackers, biscuits etc.) are being consumed in tandem.

[16] To obtain the energy-based food poverty line, we scale the basket of foods consumed by reference poor households to meet the energy requirements of adult (equivalents) aged 30-49 (2,432 kcal) and evaluate the constructed food basket at median prices of reference households.

[17] We implement an iterative procedure to identify reference poor households in terms of the energy-based poverty line. In the first iteration we arbitrarily select the bottom 50 percentile of households (in terms of total value of consumption and expenditure) to serve as the reference poor households and using the consumption patterns of this set of households identify an initial poverty line. Based on this initial poverty line, we update the set of reference poor households and recalculate the poverty line. This procedure is repeated until the poverty line converges – typically five iterations is sufficient.

also collected information on foods consumed away from the home and baked products. However, these foods represent broad food categories that do not allow for disaggregation into specific food groups and are therefore also excluded from the healthy diet food basket.[18] In contrast, the energy-based food basket includes all foods reported in the food consumption module of the survey with the exception of food consumed away from home for which we lack information on the specific caloric content.

The healthy diet basket incorporates food item preferences (of reference poor households) within each food group by assigning a greater weight to foods that comprise a greater quantity share of food group consumption (in term of food group equivalent grams). Food item costs equal food group quantities (Table 1) evaluated at median prices of reference households. Food group costs are the quantity-share weighted average costs of all food items in each food group. The cost of the total food basket is the sum of the cost of all food groups. The specific foods selected in the healthy diet basket may have a total caloric value different from the energy requirements of the reference adult. To obtain the food poverty line, we scale the food basket, and its associated cost, to meet the energy requirements of adults aged 30-49 (2,432 kcal).

Ensuring utility consistency across survey areas

A challenge arises in calculating poverty prevalence across geographic areas that demonstrate differences in food availability, prices and preferences (Ravallion, 2016; Tarp et al., 2002). For example, food production and consumption often differ due to agroecological conditions associated with specific food crop mix. Similarly, households that have greater access to commercial markets may consume different foods compared to households that are more remote. For example, as described earlier when building the food plate visualization, urban households depend more on rice for staple consumption while rural households depend more on sweet potato. Defining regional food baskets allows poverty lines to encompass different regional (or survey sample) consumption characteristics but forfeits the guarantee that poverty lines represent the same welfare level (defined in this context in terms of utility), rendering the poverty analysis incomparable. We adopt Arndt and Simler's (2005, 2007, 2010) information theoretic approach for resolving inconsistency in energy-based food poverty lines. This approach uses the observed consumption choices given prices that are incorporated in the food poverty line to impose revealed preference constraints and ensure utility consistency. Mahrt et al. (2022) extend this methodology to estimate utility-consistent healthy diet food poverty lines that in addition adhere to food group quantities defined by the FBDG. Appendix Table A3 presents the cost of the energy-based and healthy diet food baskets before and after entropy adjustments to achieve utility consistency.

Finally, for each survey area, the total energy-based diet and total healthy diet poverty line is the sum of the (utility-consistent) food poverty lines, respectively, and a regional non-food expenditure allowance. The non-food allowance is estimated using the weighted average of reported non-food expenditures (e.g., soap, school expenses, clothing, fuel, etc.) by the households whose total expenditure are close to the energy-based food poverty line. Individuals living in households with (per adult equivalent) daily total expenditure falling below the total poverty lines, respectively, are considered poor.

[18] Baked products account for 1 percent and food consumed away from home accounts for only 0.8 percent of total household food expenditure in the survey sample areas (most likely due to the rural nature of the survey), respectively.

RESULTS

Household consumption patterns

Table 2 reports average daily (per adult equivalent) food consumption quantities (in food group equivalent grams) of each food group and compares these quantities with a PNG recommended diet adapted from the Indonesian FBDG (Table 1). On average, individuals within the survey sample consume the recommended daily amount of staple and oil foods, however daily consumption of vegetables, fruits, and protein-rich foods (including different meats, fish, and peanuts) fall significantly short of recommended targets.[19] Looking within sample areas, on average, households in the Madang sample meet the daily protein-rich food group recommendation. This is expected since the Madang survey sample is located along the Ramu river and households depend on fresh fish as a major food consumption item. Conversely, individuals in ARoB and W. Sepik consume approximately one-third of the suggested daily protein-rich food group recommendation (78 and 98 grams per day, respectively), while households in East Sepik consume a little over half of the suggested daily recommendation of protein rich foods.

Table 2. Quantity (grams) consumed of each food group, per adult equivalent/day, by survey area

	Staples	Vegetables	Fruits	Protein-rich foods	Oil	N
Rec. Diet	**375**	**300**	**250**	**251**	**30**	
Survey	395	62	48	175	31	983
	(10.1)	(2.4)	(1.9)	(8.4)	(0.9)	
ARoB	391	53	31	78	22	239
	(16.5)	(4.4)	(3.0)	(6.5)	(1.1)	
E. Sepik	417	66	44	140	32	239
	(20.7)	(5.1)	(3.2)	(12.0)	(1.9)	
Madang	397	72	59	331	33	286
	(18.6)	(5.4)	(4.4)	(21.3)	(1.7)	
W. Sepik	373	52	56	98	36	219
	(23.8)	(3.5)	(3.6)	(8.9)	(2.1)	

Note: Standard errors in brackets. Quantities in food group equivalent grams. N = total observations.

Source: Authors' calculations using the RSFS (2018)

Households across the survey sample substantially under-consume vegetables and fruits. For subsistence farmers and lower income households, this may be a result of a variety of factors including limited physical capital (land or labor) to produce sufficient food stock; poor land endowments / land fertility or ongoing land degradation; lack of access to inputs (seed and fertilizer) and technology to produce fruits and vegetables (that are often more perishable and labor intensive); climate variability and/or higher levels of production risk. Households may face food security tradeoffs, requiring production decisions that substitute non-staple foods for cheaper, calorie-dense staples to ensure that bellies are full.

[19] Daily oil (fats) consumption is met across all sample areas with the exception of ARoB. A predominant source of oil in PNG cuisine derives from coconut milk. According to the Indonesia FCT, 100 grams of mature coconut meat contains 34.7 grams of oil. Coconut milk is used for flavor and texture throughout PNG cuisine and has important cultural and ceremonial value as well.

Survey data also suggest that the expenditure share of some food groups remains almost static across household expenditure quintiles (staples, vegetables and fruits) while the share of protein-rich foods increases and the share of oils declines by quintile. Higher quintile households continue to eat a relatively larger share of staple foods rather than shifting towards non-staple food groups (Table 3). A lack of knowledge of food nutrition benefits may be affecting overall diet composition in households that could afford a healthier diet. In addition, lack of market access and access to proper cold storage of perishable items may be keeping better-off households from diversifying consumption. Further analysis, outside of the scope of this paper, should evaluate nutrition knowledge across different household income levels and geographies in PNG.

Table 3. Observed household expenditure shares by expenditure quintile and sample area

		HH total expenditure quintile					Province			
	All HHs	Q1	Q2	Q3	Q4	Q5	ARoB	East Sepik	Madang	West Sepik
Staples	52	50	52	50	55	52	55	54	50	48
	(0.7)	(1.4)	(1.4)	(1.4)	(1.4)	(1.6)	(1.1)	(1.3)	(1.2)	(1.5)
Vegetables	5	6	4	5	4	4	4	5	5	5
	(0.2)	(0.4)	(0.3)	(0.5)	(0.4)	(0.3)	(0.3)	(0.3)	(0.4)	(0.4)
Fruits	7	8	8	8	6	6	5	5	10	8
	(0.3)	(0.8)	(0.7)	(0.7)	(0.5)	(0.4)	(0.5)	(0.4)	(0.7)	(0.6)
Protein-rich foods	19	15	19	20	20	21	20	18	20	17
	(0.5)	(1.2)	(1.2)	(1.2)	(1.1)	(1.3)	(1.1)	(1.0)	(1.1)	(1.1)
Oil	9	12	10	8	7	6	6	8	9	12
	(0.3)	(0.8)	(0.5)	(0.4)	(0.4)	(0.5)	(0.3)	(0.5)	(0.4)	(0.8)
Others	9	8	7	9	8	11	11	10	4	11
	(0.4)	(0.7)	(0.8)	(1.0)	(0.7)	(1.0)	(0.6)	(0.8)	(0.5)	(1.0)

Note: Standard errors in brackets.

Source: Authors' calculations using 2018 RSFS

Food basket costs

We focus on the costs of the energy-based diet and healthy diet, respectively, that are used to establish the two food poverty lines. For comparison purposes, we also estimate the cost of a least-cost healthy diet (put forward by Herforth et al., 2020). However, the least-cost healthy diet should be seen as a true minimum cost of a healthy diet because it does not consider reported household food consumption patterns which reflect factors such as availability, relative prices and local preferences. Rather, the least-cost healthy diet imputes the lowest daily cost of acquiring the PNG recommended diet by only including and summing the one or two least-cost food items in each food group by survey area (Herforth et al., 2020).[20]

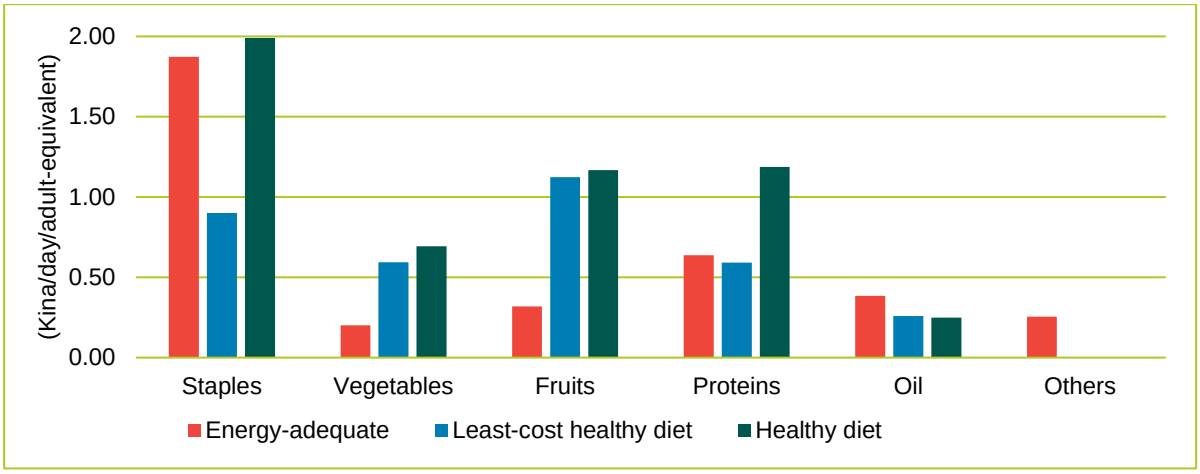
The least-cost healthy diet may underestimate the true cost of a healthy diet for poorer households given that a variety of foods are consumed within each food group, even in poorer households. For example, households in each sample area report consuming a mix of staple foods (not just the least-cost staples), which leads to the higher cost of staple foods in the healthy diet relative to least-cost healthy diet (Figure 2). Cassava and yam are among the least-cost staples in the Madang and West Sepik sample, respectively (Table A4), however they comprise only 5 and 9 percent (Table A5), respectively,

[20] In addition, the least-cost healthy diet basket is not utility-consistent (whereas the energy based and healthy basket diet are utility consistent), and hence does not allow for diet cost comparisons across survey areas.

of the total staple food consumption (grams). This example illustrates how foods chosen in the least-cost healthy diet basket may not represent foods consistent with local availability, relative prices, and preferences.

Similarly, a variety of protein-rich foods are consumed in each province. While the least-cost healthy diet estimates a cost of 0.59 PGK/AE/day to meet the protein-rich food group guidelines, the average cost of the healthy diet recommended protein portion is about 1.19 PGK/AE/day (Figure 2). This discrepancy occurs because the least-cost healthy diet assumes households in the ARoB sample would fulfill the protein-rich food group requirements via solely peanut and pork consumption (Table A6), however these items comprise only 17 and 23 percent, respectively, of the protein-rich food group basket in ARoB, while approximately 32 percent of the protein-rich food group in the ARoB sample is comprised of tinned fish.

Figure 2: Cost by food group of energy-based diet, least-cost healthy diet and healthy diet



Note: USD 1.00 = PGK 3.28 in June 2018. Figure displays population weighted averages of food group costs in regional food baskets.

Source: Authors' calculations using 2018 RSFS, FPDA food price database, HIES 2009/10 imputed food prices.

We focus the remainder of the analysis on comparisons between the energy-based and the healthy diet food basket costs and composition. Table 4 presents the total food basket cost, the non-food expenditure allowance, and the total poverty lines (sum of the respective food basket cost and non-food expenditure allowance) for the energy-based and healthy diet poverty lines, respectively. Food group costs in both baskets are based on the same reported consumption patterns, but the healthy diet basket reflects consumption patterns scaled to meet food based dietary guidelines / proportionality. Thus, the higher cost of the healthy diet food basket (relative to the energy-based) is driven by differences in the nutrition standard incorporated in the healthy diet food basket as opposed to observed household consumption quantities.

Considering the non-food expenditure allowance (which is approximately .90 PGK/AE/day), the total energy-based poverty line for each of the survey areas varies between 4.43 (Madang) and 4.65 (ARoB) PGK/ae/day (about 1.35 to 1.42 USD). While sample households in Madang face the least expensive energy-based poverty line of the survey areas, Madang households face the most expensive healthy diet poverty line (6.33 PGK/ae/day). Given the remoteness of the Madang survey sample which is situated in Middle Ramu (approximately 3 hours on a seasonal forest road and 8 hours on outboard motorboat up the Ramu river from Madang town), households in Madang face significant challenges in attaining a diet diverse enough to meet recommended nutrition standard targets.

The sample households in Madang provide a good example of the limited possibility set that remote households face to meet consumption targets. While a potential solution for Madang households could be to produce surplus sweet potato at the market and use revenue from sales to buy other diverse food, there are no local markets in the area that sell diverse food for economically viable prices.[21] In addition, since almost all households in Middle Ramu produce the same tubers (for household consumption), market sales of staple crops are thin (weak demand) and do not reap financial gains needed to support a diversified diet. Another potential solution would be for households to produce more diverse foods following nutritional targets, this comes with an intrinsic risk (or cost) of diversifying crop production from staple crops that are less expensive to produce (e.g., do not require seed and require little or no fertilizer, etc.) to more expensive fruit and vegetable crops that are less drought/flood resistant, are more vulnerable to pests, and require more inputs (labor and fertilizer, etc.). While the Madang sample may be an extreme example, regardless of remoteness, the cost of the healthy-diet food basket costs approximately 40 percent more (50 percent more in the Madang sample) than the energy-based food basket, demonstrating the increased cost of a healthy diet relative to the energy-based diet.

Table 4: Utility-consistent absolute poverty lines by province (kina/adult-equivalent/day)

	Energy-based food poverty line	Healthy diet food poverty line	Non-food poverty line	Total Energy-based poverty line	Healthy diet poverty line
ARoB	3.72	5.19	0.93	4.65	6.13
E. Sepik	3.60	5.14	0.87	4.47	6.01
Madang	3.66	5.56	0.77	4.43	6.33
W. Sepik	3.71	5.17	0.87	4.58	6.05

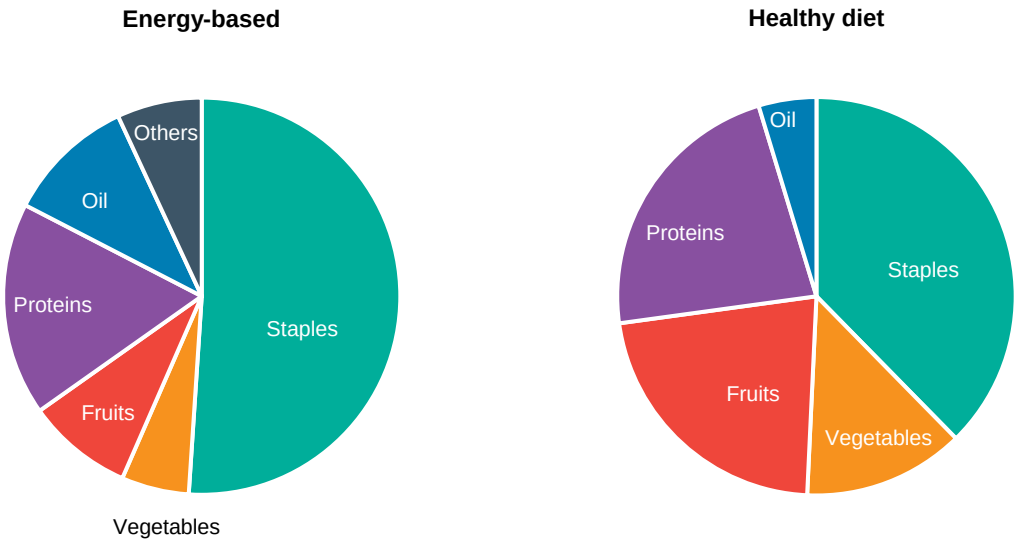
Source: Authors' calculations using 2018 RSFS

The individual food group cost shares that make up the energy-based and healthy diet food basket further explain the differences in the overall cost of the baskets, respectively. Figure 3 compares cost shares by food group for the energy-based and healthy diet, while Figure 4 makes the comparison in terms of energy (calorie) shares. The energy-based diet in both figures incorporates 'Other foods' which include discretionary foods that are not categorized into any healthy diet food basket (e.g., sugary foods). The cost share of starchy staples in the energy-based basket (Figure 3) is one-third more than that of the healthy diet (51 percent versus 38 percent). In other words, the energy-based basket relies more heavily on calorically cheap staples.[22] In contrast, fruits and vegetables make up greater overall cost shares in the healthy diet food basket, together accounting for more than one-third of the total food basket costs (Figure 3). As with expenditure shares, a greater share of dietary energy is also derived from staples in the energy-based diet (Figure 4). Nearly two-thirds (63 percent) of dietary energy (calories) in the energy-based basket are derived from starchy staples compared to just over half (54 percent) in the healthy diet basket. A greater share of dietary energy is dedicated to other nutrient-dense food groups in the healthy diet basket (Figure 4).

[21] Rather, any external (diverse) food sources would need to be transported from Madang town market to Middle Ramu (Madang survey area), whereby the consumer incurs a high transportation cost margin.

[22] While staple foods have important nutrients beyond carbohydrates, eating a disproportionate share of staples crowds out food groups rich in other essential nutrients.

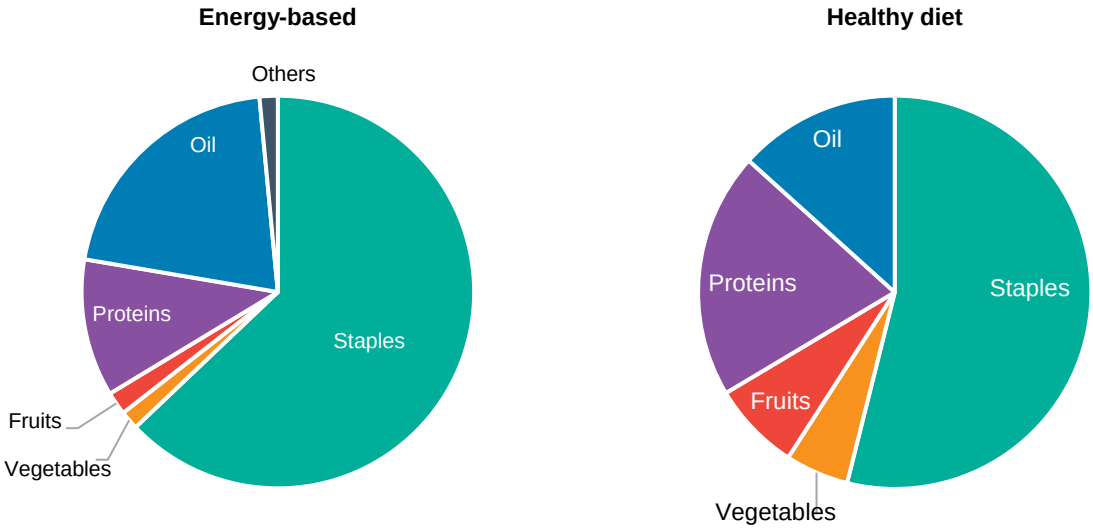
Figure 3: Cost shares by food group of energy-based diet and healthy diet



Note: Figure displays population weighted averages of regional food basket cost shares.

Source: Authors' calculations using 2018 RSFS, FPDA food price database, HIES 2009/10 imputed food prices.

Figure 4: Energy shares by food group of energy-based diet and healthy diet



Note: Figure displays population weighted averages of regional food basket energy shares.

Source: Authors' calculations using 2018 RSFS, FPDA food price database, HIES 2009/10 imputed food prices.

Poverty estimation

The 2018 household survey collected detailed household information on everything the household ate and drank within the 7 days prior to the survey, as well as reported monthly and annual non-food expenditures. Using these data, we are able to estimate a total household expenditure (income proxy) by summing the value of total food consumption and non-food expenditure per day per adult equivalent (AE). We compare the value of total household consumption and expenditure/AE/day with the cost of

the energy-based poverty line and the healthy diet poverty line, respectively. As discussed in the previous section, the healthy diet food basket (and associated poverty line) is 40-50 percent more expensive than the energy-based food basket. Thus, when comparing household total expenditure to the poverty line, it is not surprising that a greater share of households is poor relative to the healthy diet poverty line. Approximately 58 and 76 percent of the sample does not have the required expenditure to meet the energy-based and healthy diet poverty lines, respectively (Table 5).[23]

Table 5: Poverty rates and gaps, by province and expenditure quintile (kina/adult-equivalent/day)

		Poverty rate (% of population)		Poverty gap (%)	
		Energy-based poverty line	Healthy diet poverty line	Energy-based poverty	Healthy diet poverty line
All Households		58	76	24	35
Provinces	ARoB	53	73	21	31
	E. Sepik	58	73	22	33
	Madang	58	78	23	37
	W. Sepik	62	77	28	39
Expenditure quintiles	Q1	100	100	66	75
	Q2	100	100	40	56
	Q3	93	100	14	36
	Q4	0	80	0	12
	Q5	0	0	0	0

Source: Authors' calculations using 2018 RSFS

We split the survey sample by expenditure quintile, whereby households that are in quintile 1 (Q1 in Table 5) are in the bottom 20 percent (poorest) of the total expenditure distribution and households in quintile 5 are in the top 20 percent (least poor) of the total expenditure distribution. All of the individuals in the bottom 2 quintiles (bottom 40 percent) of the household expenditure distribution do not have sufficient expenditure levels (i.e., the equivalent value of *consumed* own-production in the case of subsistence households) to attain the energy-based or the healthy diet food basket with other basic (non-food) needs. The healthy diet poverty line estimate paints a stark picture of the cost of attaining a nutritious diet together with other basic needs in the sample areas of PNG, whereby only the top quintile households have sufficient expenditure levels to acquire a healthy diet while meeting other basic needs.

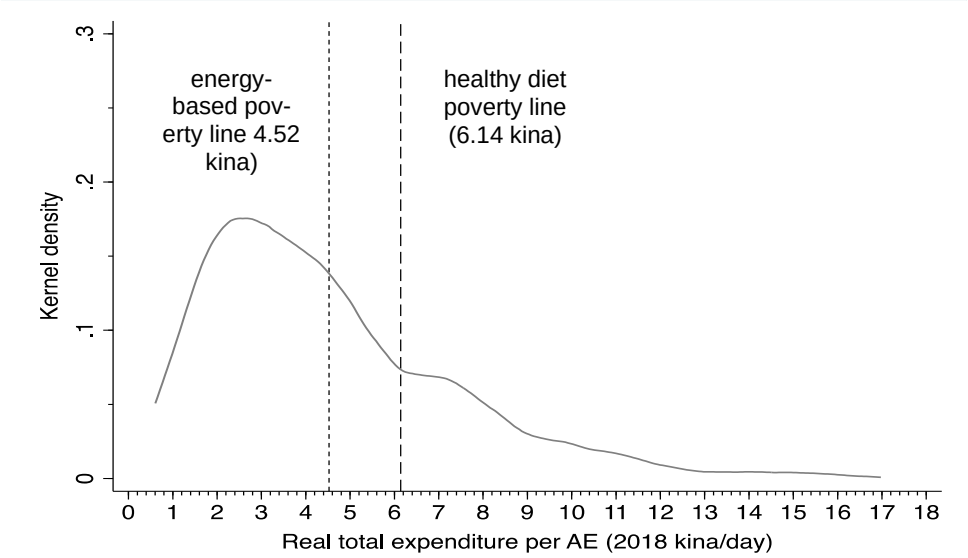
In addition to estimating the share of individuals that fall under the respective poverty lines, we also explore how far away households are from meeting the basic needs estimated in the respective poverty lines. The poverty gap of each of the poverty lines suggest that, on average, those that are under the energy-based or healthy diet poverty lines are 24 and 35 percent short of the necessary income needed to meet household expenditure requirements, respectively (Table 5).

Figure 5 illustrates the concentration of the population that falls below the energy-based poverty line, suggesting that these sample areas are not just facing nutrition deficiencies, but a large share of

[23] Several differences between this analysis and Schmidt (2020) result in slight differences in poverty rates. These include: expenditure is calculated as adult equivalent rather than per capita; only the edible portion of each item is considered while calculating calories; coconut consumption is split between green and dry coconut intake which results in different expenditure value and nutrient intake; we adopt the daily caloric needs by sex and age described in Mahrt et al. (2019) for Myanmar given similarities in BMI, weight and height data reported for PNG (Benjamin et al., 2007).

the sample is lacking the resources to consume adequate calories (just to meet the energy-based food basket) without sacrificing basic non-food needs. Thus, while currently the most urgent policy priorities are to reduce traditional energy-based cost of basic needs poverty, the healthy diet poverty line provides an important longer term policy perspective. Without advanced planning now, as the income distribution shifts to the left and the energy-based poverty line is increasingly affordable, a large share of the population will continue to face difficulty acquiring basic needs that include the healthy diet.

Figure 5: Distributions of total expenditure and the energy-based and healthy diet poverty lines (spatially adjusted kina)



Note: A spatial price deflator is derived from regional energy-based poverty lines. The real healthy diet poverty line equals population weighted mean spatially adjusted regional poverty lines.

Source: Authors' calculations using 2018 RSFS

Nutrient composition of food baskets

In addition to understanding affordability constraints of acquiring a nutritious diet, we also assess whether the two food baskets used in analysis (and the least-cost healthy diet estimation) effectively meets 15 key nutrient targets. We expect that the staple-heavy energy-based basket would not meet all nutrient requirements. Although consumption thresholds by food group are set for the healthy diet and least-cost healthy diet food baskets, nutrient requirements may not be met (even if consumption targets are met) since food basket composition differs between the two baskets and by survey area. Therefore, we estimate the nutrient content of all three baskets to evaluate whether the estimated.

Results show that the healthy diet food basket, constructed of locally consumed food items, meets the estimated average requirements (EAR) for an average 30-year-old adult (Table 6).[24] [25] The energy-

[24] EARs are the criteria for half of healthy individuals in a gender-age group to hit nutrient targets, while recommended daily allowances (RDA) are for nearly all the healthy individuals.

[25] The nutrient values used in this analysis are all based on the raw food and do not make adjustments for the nutrient retention factors associated with different cooking methods or differences in bioavailability and cultivar.

based diet does not meet recommended intake levels suggested by the EARs for zinc, riboflavin, calcium, and vitamin A. Each of these nutrients are about 30 to 50 percent lower than EARs. On average, the energy-based diet only provides half of the recommended calcium intake. While the traditional cost of basic needs approach, designed to meet energy-based diet recommendations, provides an important benchmark for poverty reduction policies, it underestimates the cost of a welfare target that aims to achieve proper nutrition and associated linkages to good health and child growth standards.

One of the most important staple foods in Papua New Guinea is sweet potato (especially in the highlands regions), however most people prefer the yellow or white-fleshed sweet potato. Compared to the yellow or white-fleshed sweet potato, the orange-flesh sweet potato provides a significantly higher quantity of Vitamin A. Assuming that 10 percent of the average sweet potato consumption per individual is orange-flesh, the energy-based food basket only meets 60 percent of the required EAR for Vitamin A. Vitamin A deficiencies are associated with increased risk of infant and child mortality, and thus are closely monitored by nutritionists across the globe (Black et al., 2008). Given that rural areas in PNG depend on sweet potato as a primary staple, and data suggest that Vitamin A remains under-consumed among sample households, nutrition extension programs to promote increased consumption of orange-flesh sweet potato could eradicate Vitamin A deficiencies in PNG in a relatively short timeframe.

Table 6: Nutrient adequacy of the energy-based, least-cost health diet and healthy diet food baskets for a 30-year-old adult

	Food Basket			Percentage of EAR for a 30-year-old adult			
	Energy-based diet	Least-cost healthy diet	Healthy diet	EAR	Energy-based diet	Least-cost healthy diet	Healthy diet
Energy, kcal	2,432	2,432	2,432	2,432	100	100	100
Protein, g	64	76	77	35	183	219	221
Calcium, mg	409	605	877	750	55	81	117
Iron, mg	17	19	24	10	163	182	230
Magnesium, mg	355	392	522	308	115	128	170
Phosphorous, mg	1,021	1,158	1,343	580	176	200	232
Zinc, mg	7	7	10	10	66	72	102
Copper, mg	1.9	2.4	2.7	0.7	271	344	385
Vitamin C, mg	155	199	224	85	182	234	263
Thiamin, mg	2.0	2.4	2.6	1.0	215	252	277
Riboflavin, mg	1.1	1.5	2.0	1.3	82	112	152
Niacin, mg	19	24	27	12	169	206	234
Vitamin B6, mg	2.5	2.4	3.4	1.4	176	170	243
Folate, µg DFE	477	629	736	250	191	251	295
Vitamin B12, µg	4.8	4.0	6.2	2.0	239	198	308
Vitamin A, µg RAE	388	630	891	530	73	119	168

Note: The table displays the population weighted average of regional food basket nutrient composition. Data shown are adequacy levels by nutrient in the food baskets shown for a representative 30-year old adult, with a 2,432 calorie diet. Nutrient composition of food baskets is based on the nutrient content of raw foods. Estimated average requirements (EARs), taken from Allen et al. 2019 with the following assumptions:

1. The protein EAR is calculated based .66 g/kg/day and the median weight for attained height of a 52.8 kg;
2. Iron takes the assumption of a moderate-absorption diet;
3. Zinc takes the assumption of a semi-undefined diet.

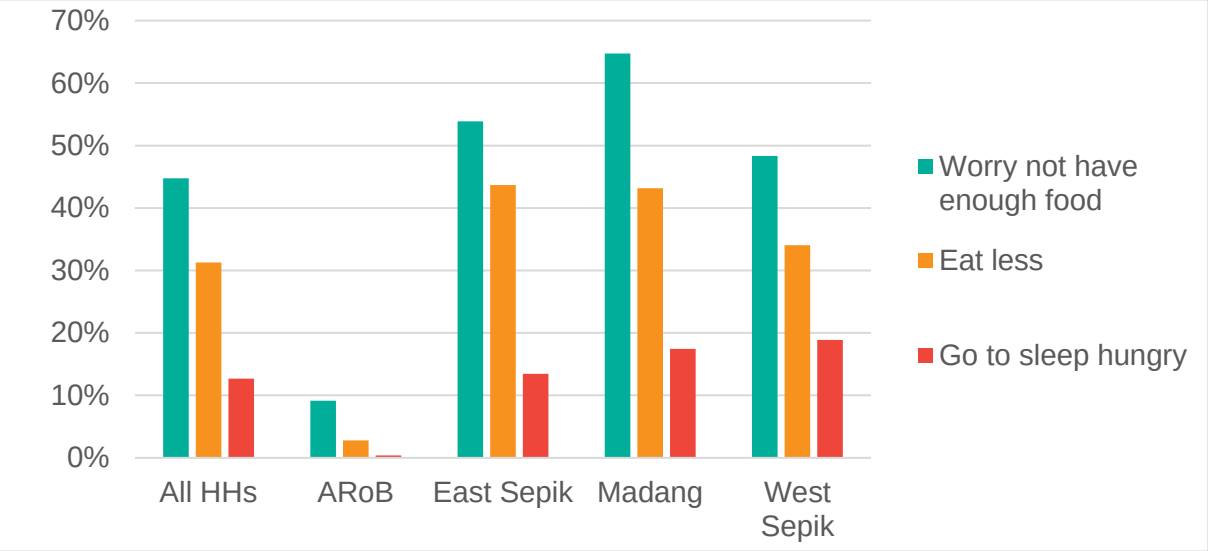
Source: Allen et al. 2020 and authors' calculations based on the 2018 RSFS and various food composition tables (Fahmida (2013), Shaheen et al. (2013), Stadlmayr et al. (2012), TKPI (2019). USDA (2016), and WHO (1979).

Perceived food security

Poverty assessments using estimated poverty lines are computationally heavy and depend on detailed, quality consumption and expenditure data to compute appropriate food baskets and non-food allowances, and appropriate household expenditure estimates. Thus, we utilize another survey module to qualitatively evaluate food security in the sample households. The 2018 survey asked a series of yes or no questions to survey respondents regarding their perception of food security during the previous 4 weeks before survey implementation. Approximately 45 percent of the survey sample responded that during the previous 4 weeks, the household was worried about having enough food to eat (Figure 6). In Madang (Middle Ramu), 65 percent of the sample worried about having enough to eat. More striking questions regarding eating less or going to sleep hungry also yielded affirmative responses, where almost one third of the sample ate less than they would have liked due to inadequate food availability.

These reflections of household perception of food insecurity echo the poverty analysis, whereby over half of the sample falls below the energy-based and healthy diet poverty lines, respectively. Similar to results displayed in Figure 6, a larger share of households in the Madang (Middle Ramu) sample struggle to meet basic energy adequacy as well as nutrition sufficiency. These results are also in line with similar estimates from the 2016-18 DHS which reported using the food insecurity experience scale (FIES) developed by the Food and Agriculture Organization (FAO), that found that about 57 percent of the population experienced moderate to severe food insecurity (Ballard et al. 2013; NSO, 2019).

Figure 6: Household perception of food security during the 4 weeks prior to the survey



Source: Authors' calculations using 2018 RSFS

DISCUSSION AND CONCLUSION

PNG joined the Scaling Up Nutrition (SUN) movement in 2016 in an effort to promote greater awareness and action towards nutrition needs in the country. The SUN Civil Society Alliance (CSA) Network has argued there are very few international donors focusing on nutrition programs in PNG (SUN, 2020). Advocates argue that a lack of capacity strengthening, and proper budget allocation are stunting PNG's

efforts to improve nutrition across the country. In addition, coordination between local and federal government actors is sorely needed to ensure financing, advocacy and programming are streamlined across government departments and programs.

Politicians and development planners often do not have a full understanding of the economic (and health) costs of persistent and pervasive undernutrition. The cost is not small. Economic studies that have followed preschool children into adulthood find undernourished children complete fewer grades of schooling and have poorer problem solving skills. International evidence has demonstrated that each additional grade of schooling increases wages by approximately 10 percent (Psacharopoulos and Patrinos, 2004). Hoddinott et al. (2008) showed that 25 years after a high-protein energy supplement was randomly provided to preschool aged children in Guatemala, the same boy children (now men) that received the supplement during preschool had 40 percent higher wages than the control group. Women of the treatment group worked primarily within the home and experienced no significant wage impact, however the offspring of the women that had received the supplement had higher birth weights and were taller than the offspring of the control group.

There is also overwhelming evidence of the large economic benefits of investing in improved micronutrient acquisition among children. For each dollar spent on: iodizing salt; providing iron supplements to mothers and children (6-24 months old); and Vitamin A interventions, reaps 30, 24 and 40 dollars in economic benefits, respectively (Hoddinott, 2015). Chronic undernutrition, similar to that suggested by the limited data available for PNG, requires not only food-based interventions that promote consumption of foods rich in micronutrients, but may also require a bundling of micronutrient supplement interventions including zinc powders. On average, across developing countries, each dollar spent on this type of nutrient bundle intervention generates approximately 18 dollars in economic benefits (Hoddinott, 2015; Hoddinott et al., 2013).

Papua New Guinea has made progress towards encouraging a policy focus on food and nutrition security. The PNG National Nutrition Policy (2016-2026) and Nutrition Strategic Action Plan (2018-2022) (NSAP) set a path to improve coordination, secure sufficient funding, and improve technical capacity of nutrition-focused program implementation. Stakeholders engaged in the review of the NSAP highlighted a need for consistent and quality data collection; a lack of such data makes tracking nutrition indicators nearly impossible.

As policy increasingly prioritizes improved nutrition outcomes, a food poverty line designed to satisfy nutrient requirements is a useful policy tool. The healthy diet food poverty line provides an upper bound cost of achieving a nutritious diet while meeting other basic needs because it considers the entire array of foods (and their associated values) that poor households consume (see Appendix A7 for the foods that are included in the healthy diet food poverty line calculated for this analysis). While energy (i.e., calorie) adequacy is important in ensuring improved welfare, nutrition adequacy is necessary to achieve greater economic growth and improved human development (including improved educational attainment, decreased disease prevalence, and decreased child stunting prevalence).

This study has identified several areas where PNG could invest greater effort and resources to improve rural household welfare. First, PNG will continue to face disruptive climate events that quickly increase agricultural vulnerability and food insecurity in remote areas with limited market access and underdeveloped support services. The government of PNG in collaboration with development partners should begin to pilot a social safety net system that can quickly provide support to vulnerable populations. Poverty analysis (such as presented here) can support dialogue on the monetary equivalent that these programs should distribute to achieve key development objectives. For PNG, a safety net program should focus on food and nutrition security, in tandem.

A variety of research has evaluated the necessary size of a social safety net transfer to ensure impact on consumption and food security indicators. Handa (2018) demonstrates that the size of the impact of a transfer is directly related to the size of a transfer. Surveying transfer values across countries suggests that the transfer size should be at least 20 percent of the household consumption value to have any significant effect on poverty reduction and food security (Handa, 2018).

Second, a concerted effort is needed to better promote the importance of nutrition in food consumption choices. While capacity strengthening is needed at all levels, a first step would be to convene government officials, healthcare workers and other key stakeholders to define and endorse a PNG food based dietary guideline that considers local consumption trends while specifying food groups quantities that are consistent with good health and nutrient adequacy. In doing so, the importance of improved nutrition for greater economic growth and human development targets should be communicated to garner high-level political leadership and commitment towards agreed nutrition outcomes. While dialogue should focus on nutrition objectives, an important component of health and development programming should also include analysis of sustainability and affordability of nutritious diets. As this analysis has shown, households in higher income quintiles are not consuming significantly greater volumes of fruits and vegetables. A greater effort to expand household knowledge of the importance of nutritious diets is not sufficient. Rather, greater access and affordability of a nutritious diet may be the largest hurdle to improving child growth indicators and other household welfare objectives in PNG.

Third, PNG must invest in more-timely data collection of key welfare indicators. An important emphasis in data collection and analysis should be paired with a pilot social safety net program. These programs must be adjusted and improved over time, and ongoing data collection and analysis is the only way to inform such programming. Monitoring and evaluation systems of nutrition-related programs within the country should identify a core set of data indicators (in addition to program specific objectives) that can inform similar nutrition targets. These indicators should be designed in consultation with trained nutritionists and government stakeholders responsible for financing and reporting on the delivery of essential nutrition services and programs.

In addition, a nationally representative household survey that collects data on detailed household consumption and expenditure should be implemented every 5 years. This survey should be accompanied by food price information to allow for household consumption-expenditure measurements (a proxy for income). The most recent Household Income Expenditure Survey in PNG was collected more than a decade ago in 2009/10.

Finally, achieving sustained food and nutrition security will need to be addressed through a variety of complementary investments that aim to improve rural and urban livelihood opportunities. This includes facilitating off-farm employment opportunities that allow households to earn additional income to purchase diverse food (and non-food) goods. Investments to better develop rural markets and supply chains (transport, cold storage, food processing and safety guidelines) will not only improve the supply of safe fresh produce, but also decrease food market prices (and domestic food price volatility) and facilitate greater household dietary diversity.

While the price of more nutritious foods will continue to influence household consumption decisions, policy formulation to improve nutrition indicators must consider the nuance involved in such decisions and adjust accordingly as more analysis becomes available. For example, Headey et al. (2018) evaluated the price and related consumption of animal source food in Ethiopia and found that households that own livestock are associated with greater levels of meat consumption, however the high market costs of animal protein incentivize producers to sell their animal source food rather than consume it. Hirvonen and Hoddinott (2017) find similar results whereby children who live in households with greater agricultural production diversity have more diverse diets, however, note the significant opportunity costs

of consuming own produce versus selling it. These results suggest an ongoing need for investment in nutrition education at all levels of society and among all age-groups.

A proper cost accounting of a nutritious diet can inform policy and aid investments (e.g., social safety net transfers, child nutrition interventions, and benefit-cost assessments of food and nutrition aid composition) to assess the true cost of a healthy diet. It also sets a benchmark for understanding poverty prevalence that accounts for the cost of achieving other development objectives of reducing child undernutrition and improving development targets linked to improved nutrition (e.g., improved school attendance, increased labor productivity and higher wage earnings). The healthy diet food poverty line for PNG provides an additional tool for assessing household welfare needs, and underlines the need for greater investment, program monitoring and policy formulation to achieve basic welfare, including improved food security and nutrition throughout the country.

APPENDIX

Table A1: Sources of food prices at various geographic levels

Price source	Food items (N)†	of N
Purchased unit price	2,493	62%
Community price	54	1%
Province price	167	4%
Mainland price‡	258	6%
Full sample price	1,026	26%
Total	3,998	100%

Note: †Respondents were asked whether anyone in their household consumed a list of 40 food items in the past seven days, 29 items of which can be grouped into recommended diet. We use the price data from RSFS 2018 for 18 of the 29 items, which are those frequently purchased items (e.g., rice, tinned fish). ‡ Mainland price includes average price of food items in Madang, E. Sepik, and W. Sepik sample.

Table A2: Sources of price data used for each food item

Price data sources	Items
HIES 2009/10	Yam, Sweet potato, Taro, Chinese Taro, Sago, Cassava, Corn/maize, Pumpkin, Pitpit, Other greens vegetables, Other vegetables, Mangoes, Other fresh fruits
FPDA	Aibika, Choko leaves, Pumpkin tips, Cabbage, Cucumber, Onions, Tomatoes, Carrots, Bananas, Pawpaw, Pineapple, Watermelon, Oranges, Mandarins
RSFS 2018	Coconuts, Rice, Flour (other than wheat flour), Wheat flour, Pasta / 2 minute noodles, Lamb and mutton, Chicken, Pork, Tinned meat, All other meat, Tinned fish, Other fish (fresh/frozen/dried), Eggs, Milk, Cooking bananas, Peanut, Edible oil, Butter/margarine/fat spread

Table A3: Cost of energy-based and healthy diet food baskets before and after entropy adjustments, by province (kina/adult-equivalent/day)

	Energy-based food basket		Healthy diet food basket	
	Pre-entropy Utility-inconsistent	Post-entropy Utility-consistent	Pre-entropy Utility-inconsistent	Post-entropy Utility-consistent
ARoB	4.40	3.72	6.33	5.19
E. Sepik	3.55	3.60	4.86	5.14
Madang	3.02	3.66	4.71	5.56
W. Sepik	3.38	3.71	4.87	5.17

Source: Authors' calculations using 2018 RSFS

Table A4: Staple foods in least-cost healthy diet basket by province

Province	Food item	Quan-tity share (%)	Calorie share (%)	Cost share (%)	Rec. Diet Quantity Cost (Kina/day)	Price / kg (Kina/kg)	Price / calo-rie (Kina/000' kcal)
ARoB	Packaged rice	50	50	75	1.47	4.30	1.20
ARoB	Cassava	50	50	25	0.48	1.57	0.43
E. Sepik	Packaged rice	50	50	82	1.85	5.00	1.40
E. Sepik	Sago	50	50	18	0.40	1.18	0.33
Madang	Cassava	50	50	55	0.57	1.48	0.41
Madang	Sago	50	50	45	0.46	1.18	0.33
W. Sepik	Yam	50	50	80	1.73	1.11	1.25
W. Sepik	Sago	50	50	20	0.44	1.18	0.33

Source: Authors' calculations using 2018 RSFS

Table A5: Staple foods in healthy diet basket by province

Province	Food item	Quantity share (%)	Calorie share (%)	Food exp. share (%)	Rec. Diet Quantity Cost (Kina/day)	Price / kg (Kina/kg)	Price / calorie (Kina/000' kcal)
ARoB	Packaged rice	50	51	56	1.61	4.30	1.20
ARoB	Cassava	23	22	8	0.53	1.57	0.43
ARoB	Sweet potato	15	16	20	1.92	1.40	1.43
E. Sepik	Sago	35	32	7	0.40	1.18	0.33
E. Sepik	Packaged rice	20	21	18	1.88	5.00	1.40
E. Sepik	Chinese Taro	9	10	13	2.92	2.06	2.10
E. Sepik	Cooking bananas	9	9	20	4.84	4.40	3.60
E. Sepik	Corn/maize	8	9	17	4.36	3.69	2.81
E. Sepik	Sweet potato	6	6	5	1.92	1.40	1.43
E. Sepik	Taro	6	6	8	2.92	2.06	2.10
Madang	Sago	25	24	5	0.40	1.18	0.33
Madang	Yam	23	22	16	1.57	1.11	1.25
Madang	Cooking bananas	17	17	37	4.84	4.40	3.60
Madang	Sweet potato	12	12	10	1.92	1.40	1.43
Madang	Packaged rice	7	8	9	2.63	7.00	1.96
Madang	Taro	6	6	11	3.90	2.74	2.80
Madang	Cassava	5	4	1	0.50	1.48	0.41
Madang	Corn/maize	4	5	7	3.63	3.07	2.35
W. Sepik	Sago	34	32	7	0.40	1.18	0.33
W. Sepik	Packaged rice	13	13	14	2.25	6.00	1.68
W. Sepik	Cooking bananas	11	11	26	4.84	4.40	3.60
W. Sepik	Taro	10	10	14	3.12	2.20	2.24
W. Sepik	Chinese Taro	9	10	14	3.12	2.20	2.24
W. Sepik	Yam	9	9	7	1.57	1.11	1.25
W. Sepik	Sweet potato	4	4	4	1.92	1.40	1.43
W. Sepik	Corn/maize	4	5	8	4.36	3.69	2.81

Note: The items with quantity share smaller than 3 percent are not included in this table, so the total quantity shares do not add up to 100 percent.

Source: Authors' calculations using 2018 RSFS

Table A6: Shares and prices (per edible quantity) of protein-rich foods of healthy diet basket by province

Province	Food item	Quan-tity share (%)	Calorie share (%)	Food exp. share (%)	Rec. Diet Quantity Cost (Kina/day)	Price / kg (Kina/kg)
ARoB	Tinned fish	32	24	50	2.51	10.00
ARoB	Pork	23	32	14	0.95	4.88
ARoB	Other fish (fresh, frozen, dried)	18	9	24	2.17	8.66
ARoB	Other nuts (e.g. peanut, galip)	17	27	6	0.60	4.00
ARoB	All other meat (including bush	9	7	4	0.75	3.85
E. Sepik	All other meat (including bush	38	32	26	0.75	3.85
E. Sepik	Other nuts (e.g. peanut, galip)	24	42	12	0.53	3.50
E. Sepik	Other fish (fresh, frozen, dried)	24	14	10	0.43	1.73
E. Sepik	Tinned fish	7	5	31	5.01	20.00
E. Sepik	Lamb and mutton	4	4	0	0.10	0.53
Madang	Other fish (fresh, frozen, dried)	53	31	23	0.43	1.73
Madang	Other nuts (e.g. peanut, galip)	20	36	6	0.31	2.07
Madang	Pork	12	19	12	0.95	4.88
Madang	All other meat (including bush	9	8	7	0.75	3.85
Madang	Chicken, fresh or frozen	4	5	47	11.21	57.47
W. Sepik	All other meat (including bush	43	37	28	0.75	3.85
W. Sepik	Other fish (fresh, frozen, dried)	24	14	12	0.58	2.31
W. Sepik	Other nuts (e.g. peanut, galip)	20	36	6	0.36	2.37
W. Sepik	Tinned fish	5	4	24	5.85	23.33
W. Sepik	Tinned meat	4	3	12	3.90	20.00

Note: The items with quantity share smaller than 3 percent are not included in this table, so the total quantity shares do not add up to 100 percent.

Source: Authors' calculations using 2018 RSFS

Table A7: Food item by food group used in healthy diet food poverty line analysis

Food groups	Items
Staples	Bananas (cooking and eating), Cassava (Tapiok), Chinese Taro, Corn/maize, Packaged rice, Sago, Sweet potato (Kaukau), Taro, Yam
Vegetables	Aibika, Choko/chayote leaves, Cucumber, Other greens, Pitpit, Pumpkin, Pumpkin tips
Fruits	Bananas, Mangoes, Oranges, Mandarin, Pawpaw, Pineapple
Protein-rich foods	All other meat (including bush meat, chicken, lamb and mutton), Other fish (fresh, frozen, dried), Other nuts (e.g. peanut, galip), Pork, Tinned fish, Tinned meat
Oil	Coconuts, Packaged vegetable oil

Note: For brevity, items with quantity shares smaller than 3 percent are not presented in this table.

Source: Authors' calculations using 2018 RSFS and HIES 2009/10

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