CHARACTERIZING THE FOOD ENVIRONMENT IN RURAL SRI LANKA AND ITS INFLUENCE ON DIET QUALITY

by
Quinn Marshall

A dissertation submitted to Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

Baltimore, Maryland
August 2022

Abstract

Background: Food environments have been understudied in low- and middle-income countries (LMICs), but may contribute to further understanding of nutrition transitions that these countries are experiencing and how programs and policies might improve diet quality. Smallholder farmers are an especially vulnerable group, including in Sri Lanka, where there are concerns about the availability and affordability of nutritious food, especially in rural, food insecure areas, and throughout the year. The Coronavirus Disease 2019 (Covid-19) pandemic and Sri Lanka's foreign exchange crisis of 2021 elevated these concerns further, with widely reported impacts on food supply chains and prices.

Objective: This study sought to characterize the food environment in 45 Grama Niladhari Divisions (GNs) in rural Sri Lanka, in terms of food availability, food costs, and affordability, and test associations with dietary diversity among smallholder farmers. In addition to furthering the evidence base on epidemiological linkages food environments and diet quality, the study aimed to contribute contextual information to an impact evaluation of the R5N program, a World Food Programme food assistance for assets (FFA) intervention aimed at strengthening resilience among smallholders in these areas.

Methods: Survey questionnaires in traditional, open-air markets and village retail shops were used to gather food availability and food price data during monthly follow-ups between December 2020 and December 2021. Food availability was assessed at baseline in terms of food variety, the presence of sufficient foods to meet food-based dietary guidance (FBDG) recommendations, and an adapted Nutrition Environment Measures for Stores-Survey (NEMS-S) score. Food costs and affordability were assessed at baseline in terms of the cost of the recommended diet (CoRD) and relative caloric prices (RCPs). This data was merged with diet data from 24-hour recalls, collected as part of the R5N impact evaluation, to test associations at baseline between dietary diversity among smallholder adults and two food environment exposures—food variety and CoRD—using multilevel Poisson regression with GN-level random intercepts. Temporal trends in food availability and CoRD were assessed over the study period and compared to secondary data from Sri Lanka's national food price surveillance system. Seasonal variation in CoRD were assessed at the national-level before and during Covid-19, using stochastic trend models.

Results: At baseline, foods to make up a healthy diet according to FBDG were highly available and affordable in the study area. CoRD was LKR 155.39 ($2.63 2011 PPP$) per person per day, representing 48% of average household food expenditure and just 15% of the households included in the R5N impact evaluation study appeared to have insufficient income to afford that diet. CoRD and food variety were not significantly associated with dietary diversity among smallholders at baseline, after adjusting for GN socio-demographic, economic, and farm size composition of study participants. In contrast, within a GN, a 10% difference in household expenditure was associated with a difference of 0.8% (95% CI: 0.5% - 1.0%) in the expected number of food groups consumed. Food availability gaps emerged in the R5N area during the second half of 2021 that may have limited physical access to sufficient food variety for FBDG, and CoRD increased by 25% the study period after adjusting for inflation, which was nearly triple the level of increase that was seen in the national price surveillance data. Covid-19 increased the volatility of CoRD nationally, though typical seasonal variation in CoRD appeared minor relative to other countries.

Conclusions: Food environment exposures measured in the study were not associated with GN mean dietary diversity among smallholders in the R5N study at baseline, though household expenditure did have a significant within-GN association. This suggests that if WFP's R5N program is successful in its attempt to improve income among smallholders, this could be sufficient to generate diet improvements. However, substantial increases in CoRD took place during the implementation of the R5N program that could alter these findings. Future work will re-examine this association, incorporating longitudinal food environment, household, and diet data.

Advisor: Dr. Jessica Fanzo, Professor
School of Advanced International Studies &
Department of International Health,
School of Public Health

Dissertation readers: Dr. Laura E. Caulfield, Professor
Department of International Health,
School of Public Health

Dr. Keeve E. Nachman, Associate Professor
Department of Environmental Health and Engineering &
Department of Health Policy and Management,
School of Public Health

Dr. Elizabeth Colantuoni, Senior Scientist
Department of Biostatistics,
School of Public Health

Dr. Andrew Thorne-Lyman, Associate Scientist (alternate)
Department of International Health &
Department of Environmental Health and Engineering,
School of Public Health

Dr. Benjamin Zaitchik, Professor (alternate)
Department of Earth & Planetary Sciences
School of Arts & Sciences

Acknowledgements

This dissertation would not have been possible without the love and support of so many friends, family members and colleagues. I would first like to thank the Sri Lankan food vendors and farming families that participated in the study. They took time out of their busy schedules to field questions from the study enumerators and share their experiences; without their willingness to invite the study into a small part of their lives, no insights could have been gained at all. I hope that knowledge generated as a result of this work will contribute to improvements in food access that may someday repay their generosity.

I would like to thank Dr. Dilini Hemachandra, who led the R5N food environment data collection. She arrived on the scene at a time when I thought that the project may no longer happen and since that day, has done nothing but provide reassurance and confidence in the face of quite uncertain field-level realities. I appreciate her thoughtfulness and fearlessness. I am also grateful to Sharunya Gnanasubramaniam and Bimali Wijerathne, research coordinators who supported the data collection, and the tireless, diligent work of all of the market enumerators from University of Peradeniya.

I've learned so many important professional and life lessons from Dr. Deanna Olney, the Principal Investigator of the R5N study. It was challenging to keep this work viable during Covid-19, but she never lost hope and took each new obstacle in stride. I will not forget the resilience and immense amount of patience that she displayed. She has been an important mentor for me since before I began this PhD journey and someone I will look up to for a long time. I am also grateful to the other IFPRI colleagues collaborated on the R5N study, including Dr. Samuel Scott, Dr. Neha Kumar, Nishmeet Singh, Gayathri Ramani, and Wahid Quabili. Thanks are also owed Dr. Bess Casswell, at University of California – Davis.

I would like to thank the Sri Lanka Country Office of the World Food Programme for buying into the idea of this research and providing me with a wide variety of support, including helping me to link with partners and attain the approval of local leaders for the study. They also provided a home for me in Sri Lanka during Covid-19, ensuring that I had everything from a valid visa to food to eat. Special thanks are owed to Saman Kalupahana, Kate Sinclair, Andrea Berardo, and Brenda Barton.

I would like to thank Drs. William Masters and Anna Herforth, who are pioneers in the field of cost of diet and food environment literature. Without the advances they had made and the advisory support they gave me, I would have been on much less steady ground.

I am grateful to the support provided by several staff members of the Johns Hopkins School of Public Health Department of International Health, including Cristina Salazar, Elisabeth Simmons, Audrey Lindahl, and Deborah Rukstelis. Cristina, Elisabeth, and Audrey helped me stay focused on graduating and never made me feel like I was too far behind. Deborah helped me navigate the treacherous waters of setting up independent contractor agreements, which at one point terrified me more than Covid-19, and I am so grateful that she saved the day.

I am grateful to the Center for a Livable Future for inviting me to be a CLF-Lerner Fellow for four of my years at JHU, and the essential funding that came along with this. I learned a lot from the CLF staff and the other fellows and will miss our journal clubs. Special thanks go to Dr. Philip McNab for his kindness and encouragement.

I would like to thank Drs. Elizabeth Colantuoni and Keeve Nachman, who served on my departmental thesis committee and defense committee. Elizabeth provided important guidance to me on the statistical methods I used and never lost patience when I seemed to come up with a new research question every week. From my first encounters with her as a professor, she took a lot of the fear out of statistics; now I find it one of the most rewarding aspects of research. Keeve has shared his food systems expertise and humor with me, and was encouraging of my research from its very early stages. I would also like to thank Dr. Andrew Thorne-Lyman, who participated in my departmental oral exam committee, was an alternate on my defense committee, and provided guidance during various points of my PhD. I learned a lot from his creative, incisive approach during a couple different non-dissertation related projects I had the good fortune to collaborate with him on.

Several of my fellow PhD students in the Nutrition program provided me with advice and guidance over the years, including Dr. Swetha Manohar, Dr. Marie Spiker, Dr. Alexa Bellows, and Dr. Kate Schneider, who arrived as a post-doc to JHU. How many dark tunnels might I have continued walking down had it not been for your perspectives?

I would like to thank Dr. Martin Bloem, who was the first person to encourage me to pursue a PhD when I was working at the World Food Programme. Martin has been a mentor to me for almost ten years now and I am always impressed with his innovative, outside-the-box thinking. Martin taught me to have confidence in what I could contribute to the field of food systems and nutrition, and to question everything.

Dr. Laura Caulfield was a guiding light throughout my time in the PhD program, helping me to shape what would often begin as abstract thoughts or questions into coherent, and even compelling, writing. She provided an essential lifeline to me during Covid-19 when we began having weekly one-on-one calls. These made me feel a lot less lonely and detached during the PhD process. I will cherish the many conversations we had.

Finally, I would like to thank my advisor, Dr. Jessica Fanzo, who has been my closest mentor since I met her ten years ago and one of my best friends. Jess provided me with the impetus to work in food systems and nutrition – I was always captivated by the passion and curiosity that she put into her work, and her well-roundedness as a human. Jess opened my eyes to the many fascinating ways one could spend their time working in this field and to the fact that creativity could play a genuine role in work life. I will continually aspire to be as honest, sympathetic, and warm as she has been to me during the time I have known her.

I would last like to thank my loving parents – Jean Marshall and Jennifer Heppenstall. They have been my strongest champions and helped to cheer me up during some of my most trying times. They have always believed in me and made it known how proud of me they are,

even when I was too irritable or stressed out to hear it. I hope that I will be able to keep making them proud as I move on to the next phase of my life. They have truly helped me to appreciate the bigger picture.

Table of Contents

List of Tables

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Appendix

List of Figures

Chapter 2

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Appendix

Abbreviations and Acronyms

BMI	Body mass index
CoRD	Cost of the recommended diet
CoRD – FP	Cost of the recommended diet – food preferences
CPI	Consumer price index
DDS	Dietary diversity score
FAO	Food and Agriculture Organization of the United Nations
FBDG	Food-based dietary guidelines
FFA	Food assistance for assets
FHP	Foundation for Health Promotion
HARTI	Hector Kobekkaduwa Agrarian Research and Training Institute
HIES	Household Income and Expenditure Survey
HPP	Health Promotion Process
ICP	International Comparison Program
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IRB	Institutional Review Board
JHU	Johns Hopkins University
kg/m2	kilograms per meter squared (for measuring BMI)
LKR	Sri Lankan rupees
NEMS-S	Nutrition Environment Measures Survey for Stores
PPP	Purchasing power parity
R5N	Building Resilience against Recurrent Natural Shocks through Diversification of Livelihoods for Vulnerable Rural Communities.
RCP	Relative caloric price
SOFI	State of Food Security and Nutrition in the World
WFP	World Food Programme
WHO	World Health Organization

Chapter 1. Introduction and Specific Aims

Diet is a leading risk factor in the global burden of disease, accounting for nearly 8 million deaths and 188 million disability-adjusted life-years among adults aged 25 or older in 2019[1]. Studies in high-income countries have sought to better understand how local food environments influence dietary quality and nutritional status, hypothesizing that differences in food access may explain health disparities, especially related to obesity[2–6]. Changes in the food environment may also contribute to the nutrition transition that many low- and middle-income countries (LMICs) are undergoing, where undernutrition, and overweight and obesity exist side by side[7]. However, in LMICs food environment research is still in its infancy[8].

Food environments are complex, comprised of multiple dimensions[9]. They influence food access in any given retail context through the availability of different types of food, food prices, the location of vendors, and food messaging, among others. Among low-income farming households in LMICs, food prices may be a critical constraint given the larger share of household income spent on food[10]. In low-income countries, consuming 2 daily servings of fruit and 3 daily servings of vegetables per person, as recommended by many dietary guidelines, is estimated to account for 52% of household income[11].

In rural LMIC contexts, household agricultural production is also thought to influence dietary intake, though the literature examining the relationship between production and dietary diversity has found only small positive effects[12]. Market access typically has stronger effects on dietary diversity; smallholders are known to purchase over half of the food they consume from markets, which also offer a greater variety of foods than what is typically feasible to grow on a farm plot, especially where farm sizes are small[12,13]. Agriculture interventions may have indirect effects on diet quality when they enhance the market orientation of farms[14,15]. These findings raise the importance of other food environment-related factors—such as market availability and affordability of food—which may also affect the diets of local populations, but are not commonly studied in these settings.

This study characterized the food environment and its effect on diet quality among adults from farming households in rural parts of Sri Lanka. Over the past two decades, as prevalence of overweight (BMI >= 25 kg/m^2) has increased from 14% to 24% among adults, high prevalence of anemia and acute malnutrition among pregnant women have persisted, mirroring the trend towards the double burden of malnutrition that is now common in LMICs[16–18]. Sri Lanka has experienced economic growth during this time, but income inequality is among the highest in the region[19]. Low-income households are especially vulnerable to rising food prices, which have been a national concern for diet quality, also due to their seasonal variation and short-term fluctuations[20].

During the study period, from December 2020 to December 2021, Sri Lanka's food system experienced shocks related to the Coronavirus Disease 2019 (Covid-19) pandemic and a foreign exchange crisis, caused by decreases in export and tourism revenues and the demands of its large outstanding debt[21]. These problems were manifest in food markets in the form of widely reported shortages, especially for imported items, and spiraling prices, which prompted the government to declare a national economic emergency in August 2021[22,23]. In this context, the study has also sought to assess changes to food availability and costs in the study area, through periodic follow-ups.

This food environment research was carried out as a sub-study within an International Food Policy Research Institute (IFPRI)-led impact evaluation of the Building Resilience against Recurrent Natural Shocks through Diversification of Livelihoods for Vulnerable Rural Communities (R5N) program, implemented by the World Food Programme (WFP) in rural areas of Sri Lanka that are prone to climate-related shocks, such as drought and floods. The R5N program aimed to enhance resilience and diet quality for vulnerable farming households through a package of asset creation activities and a healthy promotion process (HPP) activity, which included nutrition messaging. Asset creation activities centered around the rehabilitation of community and household-level irrigation systems and livelihood diversification. IFPRI conducted baseline, midline, and endline surveys at the household level in R5N communities and matched controls, which assessed diet, food security, income, agricultural practices, water security, and sociodemographic characteristics, among other themes. Due to Covid-19 restrictions, household interviews were conducted over the phone.

The food environment sub-study has complemented this household data collection with market surveys implemented in traditional open-air markets (also referred to as *pola* markets) and village retail shops in the study communities. These market surveys have assessed food availability, prices, and a range of other market and shop features. Market surveys took place on a monthly basis, though due to Covid-19 restrictions, were not possible in May, June, or August.

Though it was originally proposed to characterize study community food environments in terms of physical access to markets and retail shops as well, geospatial data for households were no longer available once household surveys were adapted for implementation via phone interviews. The shortening of household survey to fit time limitations for phone interviews also limited the detail to which agricultural production could be characterized, precluding the study of interactions between agricultural outcomes and food environments on diet (e.g. whether diet diversity among individuals from households with more diverse crop production was protected from higher market prices). The study had also proposed to assess seasonality in the cost of a healthy diet in the study area, though due to extraordinary shocks to the food system related to Covid-19 and the foreign exchange crisis, it was determined that longitudinal trends would not likely be attributable to normal seasonal effects.

Goal

The goal of this study was to characterize food environments in study communities from December 2020 to January 2022 in terms of food availability and affordability and assess their influence on diet quality, by combining market-, household-, and individual-level data. Findings from the study may inform the epidemiological literature on food environment-diet quality linkages, using newly developed metrics for measuring food environments especially pertaining to the cost of a healthy diet. Additionally, study findings will inform the impact evaluation carried out by IFPRI, which may benefit from more in-depth knowledge of market contexts in which the R5N program is implemented and how this may influence effectiveness.

Specific aims

Aim 1: To characterize the food environment in study communities at baseline in terms of food availability, and the cost and affordability of a healthy diet.

Aim 2: To measure changes in the food environment in study communities over time, in terms of food availability and the cost of a healthy diet, and compare these changes to national averages, as well as the magnitude of changes during years prior to Covid-19.

Aim 3: To test associations between food environment characteristics, including food availability and cost of a healthy diet, and diet diversity of adults in study communities.

References

1. Murray, C. J. L. *et al.* Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 396, 1223–1249 (2020).

2. Feng, J., Glass, T. A., Curriero, F. C., Stewart, W. F. & Schwartz, B. S. The built environment and obesity: a systematic review of the epidemiologic evidence. *Health Place* 16, 175–190 (2010).

3. Gustafson, A., Hankins, S. & Jilcott, S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. *J. Community Health* 37, 897–911 (2012).

4. Caspi, C. E., Sorensen, G., Subramanian, S. V. & Kawachi, I. The local food environment and diet: a systematic review. *Health Place* 18, 1172–1187 (2012).

5. Osei-Assibey, G. *et al.* The influence of the food environment on overweight and obesity in young children: a systematic review. *BMJ Open* 2, (2012).

6. Gamba, R. J., Schuchter, J., Rutt, C. & Seto, E. Y. W. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. *J. Community Health* 40, 464–475 (2015).

7. Popkin, B. M. The nutrition transition and obesity in the developing world. *J. Nutr.* 131, 871S-873S (2001).

8. Turner, C. *et al.* Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. *Adv. Nutr.* (2019) doi:10.1093/advances/nmz031.

9. Turner, C. *et al.* Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. *Global Food Security* 18, 93–101 (2018).

10. Brinkman, H.-J., de Pee, S., Sanogo, I., Subran, L. & Bloem, M. W. High Food Prices and the Global Financial Crisis Have Reduced Access to Nutritious Food and Worsened Nutritional Status and Health. *J. Nutr.* 140, 153S-161S (2010).

11. Miller, V. *et al.* Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet. Global health* 4, e695-703 (2016).

12. Sibhatu, K. T. & Qaim, M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 77, 1–18 (2018).

13. Sibhatu, K. T., Krishna, V. V. & Qaim, M. Production diversity and dietary diversity in smallholder farm households. *Proc. Natl. Acad. Sci. U. S. A.* 112, 10657–10662 (2015).

14. Snapp, S. S. & Fisher, M. “Filling the maize basket” supports crop diversity and quality of household diet in Malawi. *Food Security* 7, 83–96 (2015).

15. Jones, A. D. On-farm crop species richness is associated with household diet diversity and quality in subsistence- and market-oriented farming households in Malawi. *J. Nutr.* 147, 86–96 (2017).

16. NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: A pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* 387, 1377–1396 (2016).

17. Jayatissa, R. *et al. National Nutrition and Micronutrient Survey of Pregnant Women in Sri Lanka 2015*. (2017).

18. Popkin, B. M., Corvalan, C. & Grummer-Strawn, L. M. Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet* vol. 395 65–74 (2020).

19. World Bank. Poverty and Equity Data: South Asia. *Poverty and Equity Data Portal* (2022).

20. WFP. *Sri Lanka National Strategic Review of Food Security and Nutrition: Toward Zero Hunger*. (2017).

21. Thowfeek, R. Sri Lanka's dilemma: Pay off debt or pay for milk, meds and gas. *Al Jazeera* (2022).

22. Aneez, S. As food and energy prices soar, Sri Lankans go without. *Al Jazeera* (2021).

23. Menon, S. & Sirilal, R. Why is there a food emergency in Sri Lanka? *BBC* (2021).

Chapter 2. Review of the literature

Overview

Food environments play a key role in influencing diet quality[1]. The drivers of food choice are multilayered – while government policies have traditionally emphasized education as a means to enhance individual decision-making related to food choice, sociocultural factors, the community environment, and more distal commercial and political influences also play a role[2]. Among community-level factors is the food environment, which is described as the interface between consumers and the broader food system, where people choose and acquire foods[3]. Food environments frame food access by circumscribing the options people have to choose from for their food purchases; they may also directly influence food preferences[4]. Food environments are in turn shaped by food supply systems, including agricultural production, trade, food processing, distribution, and retail.

Despite the clear theoretical underpinnings behind the food environment-diet relationship, evidence to support and quantify this relationship has been mixed[5–7]. This has also been true for studies examining the relationship between food environments and nutrition outcomes, which have typically focused on obesity[7,8]. Authors of systematic reviews have emphasized that these results should not diminish the importance of food environments in determining diet quality, and that instead, they should motivate development of improved methods and metrics for studying food environments, including more robust research designs[6].

The literature related to physical availability and access to food, the two most commonly researched dimensions of the food environment, may provide an informative example. Physical availability of food (measured as the presence or density of different types of food vendors) and physical access (measured as the distance or travel time from consumers to these vendors) are typically assessed through Geographic Information System (GIS)-based methods, but have also shown inconclusive associations with diet, nutrition, and health outcomes[5,9,10]. However, one study of five United States cities found that only 34% of study participants' visits to food establishments over a one-week period were within their own neighborhood census tract – with the remaining establishments located outside of their neighborhoods[11]. This could explain why studies examining food environment-diet associations only within the nearest available food vendors may produce mixed results within an urban, United States context. Furthermore, it underscores the risk of over-simplifying consumers' engagement with their food environments in epidemiological research.

This review of the literature will discuss food environment research in LMICs, with a particular focus on the cost and affordability of food. It will then discuss the Sri Lanka context in terms of the nutrition transition it is undergoing and its food environment. It will also review the relationships between agricultural production, food environments, and diet quality in rural areas. Lastly, the review will examine the influence of Covid-19 on food systems and food security globally, as well as in Sri Lanka.

Emerging frameworks and existing evidence for food environment research in LMICs

Food environments are characterized across multiple dimensions, including food availability, food prices, vendor and product properties, and food messaging. A research agenda has recently taken shape to gather contextualized evidence in LMICs to evaluate these dimensions and enhance understanding of how they influence food access, dietary patterns, and health disparities[3]. This agenda also recognizes that individual factors, including income, food preferences, mobility, and time resources, contribute to individual variation in food access within any given food environment. Food environments and individual factors interact with each other as well, for example, when food advertising influences consumer preferences or when consumer purchasing power influences the types of vendors that locate in a community. An adapted version of the agenda's framework is presented below in **Figure 2.1.**

Food environment studies have proliferated in high-income countries, exhibiting some significant associations with diet and nutrition outcomes, but not for all dimensions of the food environment. Systematic reviews have found higher availability of fruits and vegetables in local food environments, as measured through household surveys (i.e. consumers' *perceived* availability) and store audits, to be associated with higher intake of fruits and vegetables and lower BMI, respective[5,7]. Greater shelf-space devoted to energy-dense snack food, indicative of availability and promotion, has been associated with higher BMI[12]. Geospatial analyses have also assessed whether distances to the nearest supermarket or fast food restaurant are related to diet and nutrition outcomes, but evidence has been mixed[5,9].

Evidence related to food environments in high-income countries may be difficult to transfer to LMICs. Food environment research came into prominence in high-income countries as a means to better understand the rise in obesity and non-communicable diseases (NCDs). It has yet to address undernutrition or the double burden of malnutrition in LMICs[6]. Transferability of findings is further complicated by the use of non-standardized indicators and methods, and the heterogeneity of vendor types[5–7]. For example, while in the United States supermarkets are used as a proxy measure for access to healthy foods, in rural Sri Lanka, low-income consumers still typically shop at traditional open-air markets for fresh foods[13].

Food systems and food environments in LMICs are rapidly transforming in ways that may place diets at risk. This was evidenced by a recent study in Nepal that estimated a quarter of infants' diet now come from junk foods, which displace consumption of nutrient-dense complementary foods[14]. Food environment studies from LMICs have to date been concentrated in a handful of middle-income countries, especially Brazil, China, Mexico, South Africa, India, and Guatemala[6]. A majority of these studies are also conducted in urban settings, with few specifically focusing in rural or peri-urban areas. Some have found that perceived availability of foods as well as access to certain vendor types (e.g. supermarkets, fast food restaurants, wet markets) do influence dietary outcomes[15–19]. As in the literature from high-income countries, studies in LMICs have most commonly focused on food availability and access, with fewer studies examining prices and affordability, and other, more difficult to observe dimensions, such as food messaging, quality, and convenience[6].

A recent systematic scoping review noted that also similar to high-income countries, studies in LMICs are limited by the lack of standardized indicators, methods, and poor designs[6]. The review issued a set of recommendations for future food environment studies in LMICs, emphasizing that they should study multiple dimensions of the food environment, harmonize indicators, and utilize more longitudinal designs. Another review specifically examined the methods, tools, and metrics available for studying food environments, finding serious gaps in those that are suitable for assessing informal market environments in particular, which predominate in rural areas of LMICs[20]. These gaps are most pronounced for convenience and desirability dimensions in the food environment, however, the review noted several suitable tools and metrics that have emerged for measuring price and affordability dimensions.

Among low-income consumers, the cost and affordability of food may be a key driver of food choice and diet quality. In socio-anthropological studies, low-income households from a variety of high-income countries have cited economic factors as leading deterrents to purchasing more nutritious food[21–23]. Evidence from the United States has found that food prices are associated with fruit and vegetable intake and obesity rates[24–26]. Healthy diets have also been found to be unaffordable in low-income countries[27–29]. Vulnerable groups in LMICs, such as smallholder farming families, may be particularly constrained due to the high share of household income that is spent on food; in the face of shocks (e.g. income losses or food price increases), they have few options other than decreasing the quality and eventually quantity of the food they purchase[30]. Increases in income, in turn, may lead to greater dietary diversity, though this association has been shown to vary by context, with some countries experiencing larger increases in dietary diversity than others for the same amount of additional income[31].

Nutrient-dense foods may be more expensive than starchy staples and energy-dense processed foods, especially in LMICs**.** In general, more energy-dense foods are lower in price on a per-calorie basis, meaning that a diet consisting of more processed foods, high in fats and sugars, may be more affordable than a diet consisting of more fruits and vegetables[24]. Another way researchers have sought to compare prices of different food groups is through 'relative caloric prices', the ratio of prices per calorie of different food groups to the price per calorie of starchy staples. In a global study, eggs and fish were each found to be 6 times as expensive per calorie as starchy staples, and dark green leafy vegetables were 16 times as expensive per calorie as starchy staples, while sugary and salty snacks were only around 2-3 times as expensive per calorie as starchy staples[32]. Relative caloric prices of nutrient-dense foods were typically higher in low-income as compared to high-income countries.

Fulfilling energy intakes may not be the only goal households have - taste, nutritional value, aspirations, and convenience also drive food choice. However, the cost of calories has been shown to be particularly important for poor households who may only begin to consider those other factors once they have met their energy requirement[24,33].

As food systems in LMICs develop, the relative caloric price of both nutrient-dense foods and energy-dense processed foods are expected to decrease. However, there are reasons to believe this may occur for energy-dense foods earlier than it does for nutrient-dense foods, which are more perishable (i.e. more difficult to import) and more challenging for supermarkets to integrate[34,35]. Post-harvest and distribution infrastructure is typically more expensive for perishable foods like fruits, vegetables, and animal source foods, which require atmosphere and temperature control; distribution networks of these foods to rural areas are especially fragmented. Analysis of trends in food prices show that since 1990, the cost of fruits and vegetables has increased relative to other foods, while processed food prices have decreased[36].

Consumption of nutrient-dense foods may be affected their own prices as well as the prices of other foods. Studies have shown that a 10% increase in the price of nutrient-dense foods (including fruits, vegetables, legumes, meat, and dairy) results in approximately a 7-8% decrease in their consumption in LMICs[37,38]. Increases in the price of staple foods may also reduce consumption of nutrient-dense foods by reducing the household income left over after purchase of staple items[30,39]. With such a large portion of household income needed to purchase the recommended daily servings of fruits and vegetables (52% in low-income countries), reductions in income could have negative effects on diet quality[40]. In this context, the low cost per calorie of energy-dense processed foods may also have negative implications for consumption of nutrient-dense foods.

As mentioned, in the previous five years, new tools and metrics have emerged to measure food costs and affordability that are suitable for LMICs. Unlike relative caloric prices, which are food group-specific, these estimate overall diet costs for diets that adhere to normative guidelines, such as food-based dietary guidelines (FBDGs), or nutrient requirements, including essential micronutrient requirements and acceptable macronutrient ranges[41]. Energy sufficient diets have also been measured, which provide a useful comparison to cost of healthy or nutrient adequate diets, highlighting the additional cost of consuming a quality diet beyond the cost of quantity, in terms of kilocalories required.

Cost of diet measures can also be compared to household food expenditure estimates to determine the affordability of nutritious diets and the prevalence of households that cannot afford them (e.g. assuming households with food expenditure lower than 100% of the cost of diet cannot afford it). It has been estimated that in 2017, 10% of the global population could not afford an energy sufficient diet, but 60% could not afford a healthy diet that adheres to FBDGs[a].

---

[a] These are 'upper-bound' estimates in the 2020 State of Food Security and Nutrition Report, which assume that households do not alter the share of their income that they spend on food (i.e. non-food expenditure continues to be directed to non-food items). This report used 42% and 50% of total income as the share that is dedicated to food in lower middle- and low-income countries, respectively[29].

In low income and lower-middle income countries these results are higher, with 91% and 75% of households unable to afford a healthy diet, respectively[29]. It has also been noted that within countries, rural, remote regions may have larger affordability gaps and that within households, vulnerable life-cycle groups, especially adolescent girls and pregnant and lactating women have higher costs of nutrient-adequate diets[29,42].

Studies using these new metrics to date have relied on secondary data sets accessed from national food price surveillance systems, such as consumer price inflation (CPI) monitoring, or from the World Bank International Comparison Program (ICP), which gathers price data on a common basket of goods to compare price levels in different countries and generate purchasing power parity (PPP) conversion rates. These data sources have certain limitations related to the food lists used, which may not always include locally important food items, and data collection sites that sample disproportionately from formal markets in urban centers, which may not reflect prices in rural areas[29,43]. Other studies have made use of imputed prices from household income and expenditure surveys, which are more representative of rural areas, but are also subject to respondents' recall[28]. Use of cost of diet indicators for community-level food environment research relying on primary data would require additional adaptation to determine appropriate food lists and data collection sites[20].

The nutrition transition in Sri Lanka

Sri Lanka is experiencing a double burden of malnutrition that is characteristic of other LMICs undergoing the nutrition transition. Overweight and obesity were previously considered problems of high-income countries, but over the last several decades many LMICs have experienced rapid increases in overweight and obesity, even where undernutrition has remained high[44,45]. This double burden is manifest even within the same communities and households[46]. Sri Lanka has achieved significant progress in reducing the prevalence of child stunting, from 32% in 1987 to 17% in 2016, however, current prevalence of anemia among pregnant women

(35%), low birthweight babies (18%), and child wasting (15%) remain relatively unchanged over the past decade[47,48,49]. Meanwhile, from 2000 to 2016, female overweight[b] has increased from 19% to 28% and female obesity[c] has increased from 3% to 8%, while in men, overweight has increased from 12% to 19% and obesity from 1% to 3%[50].

Overweight and obesity are increasing rapidly in rural areas. Urbanization is traditionally considered a key driver in the nutrition transition, associated with increased intake of foods high in fat and sugar, processed foods, and food consumed away from home, as well as more sedentary lifestyles[51]. However, since 1985 mean body-mass index (BMI) has been increasing at the same rate or faster among rural populations as compared to urban populations in most low and middle-income regions of the world[52]. This is true for Sri Lanka as well, where mean BMI among rural adults has grown by 14% since 1985 compared to 12% among urban adults, narrowing the urban-rural gap in mean BMI from 1.07 kg/m^2 to 0.85 kg/m^2, with an even narrower difference among women specifically, due to rapidly increasing BMI among rural women[52].

Improving diet quality among adult men and women is an important objective for ending malnutrition in all its forms in Sri Lanka. Women of reproductive age are an especially critical group due to their elevated nutrient needs, especially during adolescence and pregnancy, and their reduced energy intakes relative to men[53]. Iron-deficiency anemia during pregnancy as well as thinness, which affects 18% of pregnant women in Sri Lanka, could increase risk of low birthweight babies and perinatal morbidity[54]. Women also show higher prevalence of overweight and obesity than men[50].

Data on dietary patterns are limited in Sri Lanka, though it is likely that significant numbers of adults are not consuming adequate fruits and vegetables**.** A World Health Organization (WHO) survey in 2015 estimated that 72% of women and 73% of men consume

---

[b] Adult overweight measured as a body mass index (BMI) of 25 kg/m^2 or higher
[c] Adult obesity measured as a BMI of 30 kg/m^2 or higher

less than 400 grams of fruits and vegetables per day, as part of global dietary recommendations. Furthermore, 25% of women and 28% of men reported “always or often” consuming processed foods high in salt[55]. An earlier survey also reported that 61% of women and 85% of men surpassed the nationally recommended maximum of 11 servings of starchy staples per day, and on average men consumed 5 more servings of starches per day than women[56].

The food environment context in rural Sri Lanka

The ‘supermarket revolution’, a term coined to describe diffusion of modern food retail, has been taking place in the South Asia region more recently relative to other regions, with Latin America and Central Europe among the first wave regions (in the early 1990s), Southeast Asia in the second wave (mid to late 1990s), and India beginning in the 2000s, as part of the third wave[57]. In this transition process, as modern retail begins to account for a larger percentage of overall food retail, it gradually expands from large cities to smaller cities, from processed and semi-processed into fresh foods, and finally begins modernizing and vertically integrating supply chains, often instituting higher quality standards. This process has been taking place at a faster pace in the Asia region than it did other regions, but unique features have also presented challenges, including the predominance of traditional wholesale markets, the large percentage of smallholder farmers, and especially in South Asia, fragmented and often low-quality infrastructure.

Most low-income, rural consumers in Sri Lanka rely on traditional open-air markets, known as *pola,* for their weekly grocery shopping. Pola markets operate once or twice a week, providing a physical location for the buying and selling of food and non-food items. Food in the market is sourced both from major wholesale centers as well as from local farmers. Especially in rural areas, they serve as economic and social centers within the community[58]. Though modern retailers, such as the state-owned Lanka Sathosa or Cargill’s FoodCity, also exist in rural areas, supermarket penetration is low compared to other countries in the region, and supermarkets have yet to diffuse over low-income consumer segments and fresh food product categories[59,60]. Market infrastructure is poor in many parts of the country, with pola markets often lacking permanent covering, cold storage, and sanitation. Varying quality and density of road infrastructure may lead to differences in food availability and accessibility within districts, particularly among communities located far from district distribution centers[61].

While modern grocery retail is not yet the norm in rural Sri Lanka, processed and ultra-processed foods[d], which are often high in salt and sugar and low in micronutrients, are pervasive, supplied by multinational and domestic food manufactures alike. One qualitative study among students in two rural districts of Sri Lanka noted the increased availability of these foods, especially in village retail shops and mobile vendors, as well as the increased advertising of these foods through mass media[62]. By linking with traditional retailers, food manufacturers are able to expand distribution to even isolated areas, and while this may provide an opportunity to increase coverage of nutritious processed foods as well (e.g. fortified foods), such modern-to-traditional supply chains may contribute to overweight and obesity[35]. In contrast to pola markets, small village shops offer relatively few fresh foods, focusing instead on the sale of processed and ultra-processed foods and beverages, including instant noodles, salty snacks, biscuits, processed meats, and sugar-sweetened beverages, with a limited range of starchy staples.

Though Sri Lanka has benefitted from steady gains in infrastructure development over the past two decades, these have not been spread evenly across the country, which may affect physical access to built food environments. Market and road infrastructure in the Northern and Eastern Provinces sustained heavy damage during conflicts between the Government of Sri

[d] Food processing may include milling, cooling, freezing, smoking, heating, canning, fermenting, and fortifying, among others, none of which are inherently bad for nutrition and some of which may even be beneficial, however, for the purposes of this study “ultra-processed foods” refer to those foods wherein processing has resulted in altered nutrient content, such that unhealthy ingredients (saturated and trans fats, sugar, and salt) are disproportionately high, and fiber and micronutrients are limited. While basic and moderately processed foods can include healthy foods, such as canned vegetables and whole grain breads, ultra-processed foods refer to high processed food categories, including salty snacks, sugar-sweetened beverages, and sweets.

Lanka and the Liberation Tigers of Tamil Elam (LTTE) from 1983 to 2006, which were concentrated in these areas, where the majority of the Tamil ethnic group is located[63]. After the conflict, it was reported that only 20-25% of roads in the Northern Province were in good condition[64]. Irrigation tanks were also damaged, reducing smallholder households' capacity to manage climate shocks and seasonality[65]. Poor infrastructure has constrained market access in the Northern and Eastern Provinces, as well as Monaragala District in the Uva Province (where infrastructure has been historically underdeveloped), and is believed to contribute to intra-district variation in the availability of diverse foods[61]. Though infrastructure investments have targeted these areas in recent years, inequalities persist: the Northern, Eastern, and Uva Provinces have the lowest median household income and highest percentage of poor households in the country[66].

New cost of a nutritious diet metrics have also been tested in Sri Lanka, revealing a high percentage of households that cannot afford a nutritious diet. The 2020 *State of Food Security and Nutrition in the World* (SOFI) report estimated that in 2017, the cost of a recommended diet (CoRD) (i.e. the minimum cost of following the diet recommended in food-based dietary guidelines[e]) was nearly five times higher in Sri Lanka than a food basket that meets only caloric needs, and that 54% of the population could not afford this diet[29]. An earlier study had also examined variation across Sri Lanka's 25 districts, finding that the most expensive CoRD[f], in the district of Colombo, was 43% higher than in Jaffna, where CoRD was cheapest[67]. Vegetables, dairy, and oils exhibited the most price variability. Unaffordability is also driven by regional variation in income levels. In Sri Lanka, 47% of total household income is held by the wealthiest 20% of households, the highest in the South Asia region, and large income disparities exist between urban Colombo and rural areas, especially in former conflict-affected zones[61,68].

[e] Note that in this global study, CoRD is not based on Sri Lanka's national FBDG, but rather ten quantitative FBDG's from different regions of the world (not including Sri Lanka) that were individually (minimum) costed and then averaged. Price data were obtained from the 2017 World Bank ICP report.
[f] These estimates from Dizon and Herforth (2018) use 2017 CPI data from Sri Lanka to estimate the minimum cost of a regional composite FBDG, based on FBDG from Bangladesh, India, and Sri Lanka.

Food prices in Sri Lanka are rising and subject to short-term volatility, which may affect both diet outcomes and livelihoods. All foods in Sri Lanka have experienced a positive trend in nominal prices since 2008, due to increases in consumer demand (from increased disposable income), inflation, and taxation in the foods sector. Fish, chicken, and vegetables have experienced larger increases, potentially due to changing consumer preferences for these nutrient-dense foods[61]. Prices are also subject to short-term volatility, due to complex, shifting trade policies, the seasonal nature of agricultural production, climate shocks, and increasing costs of production.

The role of agricultural production and markets in diet quality among rural smallholders

New frameworks have also been adapted for 'natural' food environments, as distinct from the 'market' food environments previously described, recognizing that cultivated landscapes (e.g. fields, gardens, orchards, and aquaculture), in addition to wild food environments, are important food access points, especially among rural farmers[69]. Agriculture has long-been identified as an important sector to leverage for nutrition-sensitive programming[70]. The pathways by which household production may enhance diets for farming households are both through increased on-farm availability of nutrient-dense foods for consumption, as well as increased income from agricultural sales that can be used to purchase nutrient-dense foods. The majority of smallholder farmers are net buyers, meaning that they supplement their own production with market purchases to satisfy their food demand[71].

Current evidence supports modest impacts of household agricultural production on diet quality. In a meta-analysis of studies examining the effects of household agricultural production diversity on dietary diversity, it was estimated that a household would need to increase the number of crop or livestock species it produces by 16 in order to increase dietary diversity by one additional food group[72]. In contrast, a review of evidence from nutrition-sensitive agriculture studies identified a number of programs that managed to improve women's and children's dietary diversity and consumption nutrient-rich foods, but these typically targeted households with women and young children specifically and added nutrition-specific interventions like behavior change communication and micronutrient-fortified foods[73].

For smallholder farming families, improving market access may be a more effective means to achieve improvements in diet quality than production diversification on its own. Studies that include a variable for market access regularly find that its association with dietary diversity is much stronger than that of household production[72,73]. A study in Ethiopia also noted that while market purchases made up 42% of the average farming household's caloric consumption, they represented 80% of dietary diversity, meaning that markets were more important for access to diverse nutrient-dense foods than for starchy staples[74]. Evidence also supports an interaction between market access (measured as distance to the nearest market) and production diversity, whereby households in remote areas with limited market access have a stronger association between production diversity and diets, and households located closer to markets could compensate for lack of production diversity with market purchases[75].

Agricultural activities in Sri Lanka are centered around two monsoon seasons – *maha,* the primary season from September to March, and *yala,* the secondary season from May to August. Rice is the staple food of Sri Lanka and grown in a variety of conditions, though due to its high water requirements, may be replaced with other crops, such as pulses or groundnuts, during the *yala* season in dry zones lacking irrigation infrastructure[76]. As previously mentioned, this seasonal pattern is thought to affect food price volatility, though studies have not quantified this seasonal variation in Sri Lanka, as has been done in Africa, where seasonal gaps (the difference between the maximum and minimum monthly prices) were large, as high as 61% for tomatoes, 33% for maize, and 16% for rice[77]. Another analysis for Malawi examined seasonal variation in the cost of a nutritionally adequate diet, estimating a seasonal gap between 10 and 14% among markets where such a diet was feasible (i.e. not including markets that could not supply sufficiently nutritious foods)[78]. In recent years in Sri Lanka, climate change has resulted in monsoon onsets that are less predictable, which may further accentuate season patterns[76].

The intensity and frequency of climate-related shocks have also increased. The worst drought in 40 years took place in Sri Lanka during 2017-2018, resulting in a 45% decrease paddy rice production during the 2016/2017 *maha* compared to the previous *maha* season, and a 22% increase in the number of food insecure households[79,80]. The most common reported coping mechanisms were eating less preferred foods and reducing meals[80]. Smallholder farmers in the dry zone were most affected, especially those practicing rainfed agriculture, but also those with access to irrigation due to drastically reduced water levels in irrigation tanks and reservoirs, which limit spatiotemporal transfers of water[79].

Covid-19 and its effect on food systems and food security

The emergence of Covid-19 in early 2020 has had widespread impacts on food systems, affecting both producers and consumers, as well as actors all along the supply chain. While fundamentally a health crisis—which to date has resulted in over 6 million lives lost globally—Covid-19 quickly precipitated an economic crisis as well, as efforts to control it through curfews, social distancing, and other restrictions caused disruptions in trade and livelihoods[81]. In the food system there were delays through supply chains, increased prices for farming inputs, stoppages at food processing facilities, and closures of food markets, including high-density open-air markets in LMICs, which limited physical access to food especially during the early part of the pandemic[82,83]. Initial increases in global food prices were eventually moderated in 2020, though these began to rise again in 2021, driven in part by high shipping and transport costs, and there are signs that further inflation could continue[84].

However, the most profound effects of Covid-19 on the food system have been on demand side, as many people were faced with temporary unemployment and reductions in their income. This reduced purchasing power affected food choices, as consumers in many countries reduced consumption of more expensive nutrient-rich and perishable foods in favor of shelf-stable staple foods, or in more extreme cases, reduced consumption altogether or skipped meals[82]. Fearing shortages, many consumers also resorted to hoarding[83,85]. These changes in food demand posed a shock to food supply as well, reducing the incomes of producers of perishable foods in some cases, and disrupting stable supplies of food in the face of abrupt demand swings.

As is generally the case during shocks, poor households are most at risk because they already devote a large portion of their budget to food and they have limited coping strategies available to deal with losses[30]. Women may have been disproportionately affected by income and job losses from Covid-19, also experiencing increased burdens of child care and food preparation, and decreased autonomy while men were home more often[86]. At a national level, LMICs also struggle more during shocks due to the limited financial resources they have to funnel relief to vulnerable groups via robust social safety nets.

Sri Lanka had its first confirmed case on March 11, 2020 and by late March 2020, the government put in place a national 24-hour curfew, lifted only during short windows in areas of low risk, which stayed in effect intermittently through early May[87]. Though inter-district travel within Sri Lanka was also restricted, providers of food—including farmers, fishermen, transporters, and some food processing facilities (e.g. rice milling)—were not subject to these restrictions[87,88]. Qualitative research among vegetable farmers still reported reduced income, due to scarcity and difficulty in accessing key inputs, such as seeds and fertilizer, challenges in delivering produce to markets, and lower prices offered by collectors[89]. Experiences of food insecurity were reported by farmers and the general public alike, with one national phone interview finding that almost 40% of respondents had experienced complete stoppages in their income during the early months of the pandemic and over 80% had reduced consumption of fish, meat, and eggs[90,91].

The emergence of the Delta variant in Sri Lanka in May 2021 brought with it the largest spike in Covid-19 cases, eventually reaching a high of nearly 6,000 daily new cases in August 2021[92]. However, the most dramatic impacts on daily life were caused by a foreign exchange crisis that careened out of control during the summer of 2021. Sri Lanka had built up an unsustainable amount of external debt over many years of borrowing and with Covid-19 related shortfalls in foreign exchange earnings from tourism and exports, was struggling to continue servicing this debt. To stem the outflow of foreign currency, Sri Lanka had restricted imports of many items, including some foods; while the intention was to continue importing essential food items that were not produced in sufficient supply domestically (e.g. milk powder), limited foreign reserves also made this difficult, causing shortages, with essential food items often stuck in the Colombo port[93]. As reports of queues for food became regular, food prices spiraled due to the scarcity, in addition to the devaluation of Sri Lanka's national currency[94].

Figure 2.2 shows 2021 trends in Covid-19 cases as well as the food consumer price index (CPI), along with key events and responses taken by the government to contain the virus, while protecting its economic stability. Price controls have historically been a policy tool used by the government to protect low-income consumers access to food and these were also used during the latest economic crisis, but the pressure placed on importers and retailers by these controls were causing further shortages and black markets (where foods were illegally sold at higher prices), so were partially lifted in September 2021[87,95].

One particularly damaging use of import restrictions may have been the government's ban on imports of agro-chemical inputs, including fertilizers and pesticides, announced in April 2021. This was promoted as a step towards more sustainable food production that would also allow Sri Lanka to save foreign reserves, but in a phone survey farmers reported high dependence on these inputs and being unprepared for such a sudden shift to organic[96]. Though the ban was lifted after just seven months, it was blamed for low yields following the May-

August *yala* season, which reportedly contributed to shortages and higher rice and vegetable prices[97].

Summary

Food environments are recognized as a central component of food systems, which may partially explain dietary and health inequities, but evidence to quantify these relationships—especially considering the multi-dimensional nature of food environments—is still lacking. Studies assessing food environments in LMICs are growing in number, though their quality is often limited by cross-sectional research designs and lack of standardized indicators. New metrics for estimating food costs and affordability, cited in socio-anthropological literature as key drivers of food choices, have recently emerged. Though these metrics have to date been used primarily in global studies, opportunities exist to adapt them for use in the study of community-level food environments.

Sri Lanka is an LMIC with a nutrition transition taking place, but little known about food environments how it may influence diets. The present study has taken place in remote, rural areas, where physical access to food is thought to be affected by seasonality and poor infrastructure, and affordability may be affected by price volatility and income shocks. Nationally, it is estimated that over half of Sri Lankans cannot afford a healthy diet and district-level estimates indicate that this could be even higher in poorer, more rural districts. However, it is not known what further variation may exist at a community-level and at different times of the year.

Covid-19 has disrupted global food systems and threatened food security, including in Sri Lanka, which has experienced a double shock, in combination with its foreign exchange crisis. While Covid-19 forced temporary unemployment and income losses, the economic crisis has generated changes in food prices, evidenced in a runaway food CPI towards the end of 2021. Still, it is not known whether the reports of food shortages and high prices will also apply in rural areas, where markets also source foods locally, and how Covid-19 may have impacted the normal seasonal pattern of the cost of a nutritious diet, which may behave differently from food CPI. Fuel price increases that also accelerated in 2021 may have increased the price of distributing foods to remote areas[98].

The present study therefore contributes to two different areas of evidence:

First, epidemiological evidence on food environment-diet linkages in remote, rural communities of Sri Lanka during Covid-19. It will do this by combining market surveys in traditional open-air pola markets and village retail shops with household and diet data collected from household surveys among smallholder farming families in the same communities. Though farming households in these areas also have access to food from their own cultivated food environments, they are still likely to rely on markets to meet their food needs. The study will specifically utilize a recently developed cost of diet indicator – CoRD – which to date has only been assessed using secondary data and has not been used to test associations between food costs and diet quality at a community level.

Second, the study will provide implementation research evidence, by embedding within an impact evaluation of a nutrition-sensitive agriculture program being implemented by WFP. This program and evaluation are described in more detail in the "Study Setting" section of the following chapter. In addition to creating the opportunity to contribute epidemiological evidence by bringing together market, household, and diet data where they otherwise wouldn't have been available, the relationship between this food environment sub-study and the broader impact evaluation may shed light on the context WFP's program is implemented in. Reviews of nutrition-sensitive agriculture literature have noted the need for studies to integrate more food environment analysis—acknowledging that the food environment may modify program effects on diet and nutrition[73]. Though these interactions between program participation and food environments are not tested in this dissertation, which examines food environment and diet associations only at baseline, future work will do this. It is hoped that food environment evidence in a program evaluation context may also be useful for the design of future programs and policies, especially as Sri Lanka's seeks a path to recovery following Covid-19 and its economic crisis.

Figure 2.1. A food environment framework for research in LMICs

Food environment dimensions

- Availability – presence of a food vendor or product
- Prices – monetary value of food products
- Vendor properties – type of outlet, location, opening hours, services
- Product properties – food quality, safety, shelf-life, packaging
- Food messaging – promotion, advertising, and labeling of foods

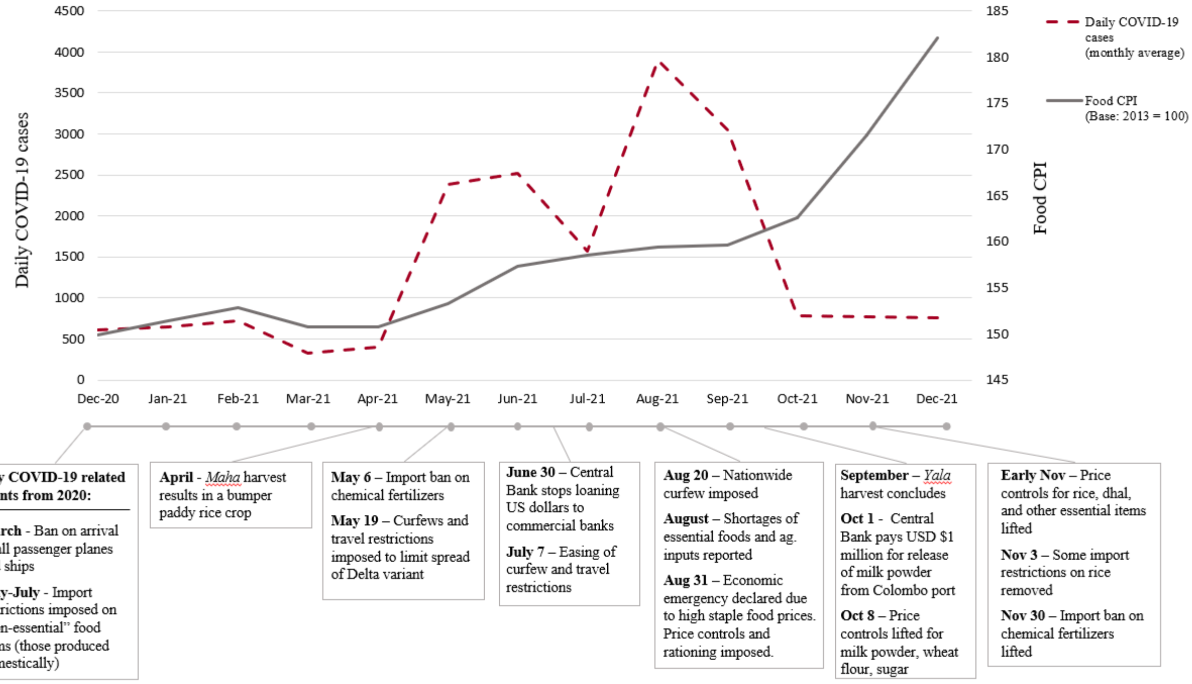
⟷

Individual Factors

- Accessibility – physical distance to food outlets, time, mode of transportation
- Affordability – purchasing power
- Convenience – time and effort needed to prepare, cook and consume a food product
- Desirability – preferences, tastes, culture, attitudes, knowledge

Adapted from Turner et al (2018)[3] and HLPE (2017)[1]

Figure 2.2. Daily Covid-19 cases and food consumer price index (CPI) during the study period



References

1. HLPE. *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition*. (2017).

2. Mozaffarian, D., Angell, S. Y., Lang, T. & Rivera, J. A. Role of government policy in nutrition-barriers to and opportunities for healthier eating. *BMJ* 361, k2426 (2018).

3. Turner, C. *et al.* Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. *Global Food Security* 18, 93–101 (2018).

4. Global Panel on Agriculture and Food Systems for Nutrition. *Food systems and diets: Facing the challenges of the 21st century*. https://www.glopan.org/sites/default/files/Downloads/Foresight Report.pdf (2016).

5. Caspi, C. E., Sorensen, G., Subramanian, S. V. & Kawachi, I. The local food environment and diet: a systematic review. *Health Place* 18, 1172–1187 (2012).

6. Turner, C. *et al.* Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. *Adv. Nutr.* (2019) doi:10.1093/advances/nmz031.

7. Gustafson, A., Hankins, S. & Jilcott, S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. *J. Community Health* 37, 897–911 (2012).

8. Gamba, R. J., Schuchter, J., Rutt, C. & Seto, E. Y. W. Measuring the food environment and its effects on obesity in the United States: a systematic review of methods and results. *J. Community Health* 40, 464–475 (2015).

9. Feng, J., Glass, T. A., Curriero, F. C., Stewart, W. F. & Schwartz, B. S. The built environment and obesity: a systematic review of the epidemiologic evidence. *Health Place* 16, 175–190 (2010).

10. Lytle, L. A. & Sokol, R. L. Measures of the food environment: A systematic review of the field, 2007-2015. *Health & Place* 44, 18–34 (2017).

11. Liu, J. L., Han, B. & Cohen, D. A. Beyond Neighborhood Food Environments: Distance Traveled to Food Establishments in 5 US Cities, 2009-2011. *Preventing Chronic Disease* 12, E126 (2015).

12. Rose, D., Bodor, J. N., Hutchinson, P. L. & Swalm, C. M. The importance of a multi-dimensional approach for studying the links between food access and consumption. *J. Nutr.* 140, 1170–1174 (2010).

13. Jayatillake, P. J. & Mahalianaarachchi, R. P. Behavioral pattern of fruit & vegetable consumers in the 'Pola' (Fair) system in Monaragala district in Sri Lanka. *Jiangsu nong ye xue bao* 3, 33 (2007).

14. Pries, A. M. *et al.* Unhealthy Snack Food and Beverage Consumption Is Associated with Lower Dietary Adequacy and Length-for-Age z-Scores among 12–23-Month-Olds in Kathmandu Valley, Nepal. *J. Nutr.* 149, 1843–1851 (2019).

15. Wang, R. & Shi, L. Access to food outlets and children's nutritional intake in urban China: A difference-in-difference analysis. *Ital. J. Pediatr.* 38, (2012).

16. Duran, A. C., de Almeida, S. L., Latorre, M. do R. D. O. & Jaime, P. C. The role of the local retail food environment in fruit, vegetable and sugar-sweetened beverage consumption in Brazil. *Public Health Nutr.* 19, 1093–1102 (2016).

17. Jaime, P. C., Duran, A. C., Sarti, F. M. & Lock, K. Investigating environmental determinants of diet, physical activity, and overweight among adults in Sao Paulo, Brazil. *J. Urban Health* 88, 567–581 (2011).

18. Vedovato, G. M., Trude, A. C. B., Kharmats, A. Y. & Martins, P. A. Degree of food processing of household acquisition patterns in a Brazilian urban area is related to food buying preferences and perceived food environment. *Appetite* 87, 296–302 (2015).

19. Chor, D. *et al.* Association between perceived neighbourhood characteristics, physical activity and diet quality: results of the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). *BMC Public Health* 16, 751 (2016).

20. Ahmed, S. *et al.* Suitability of Data-Collection Methods, Tools, and Metrics for Evaluating Market Food Environments in Low- and Middle-Income Countries. *Foods* 10, 2728 (2021).

21. Dowler, E. Budgeting for food on a low income in the UK: The case of lone-parent families. *Food Policy* 22, 405–417 (1997).

22. Wiig, K. & Smith, C. The art of grocery shopping on a food stamp budget: Factors influencing the food choices of low-income women as they try to make ends meet. *Public Health Nutr.* 12, 1726–1734 (2009).

23. Dachner, N., Ricciuto, L. & Sciences, N. Food purchasing and food insecurity among low-income families in Toronto. *Can. J. Diet. Pract. Res.* 71, e50-6 (2010).

24. Drewnowski, A. & Specter, S. E. Poverty and obesity: The role of energy density and energy costs. *American Journal of Clinical Nutrition* vol. 79 6–16 (2004).

25. Drewnowski, A., Aggarwal, A., Hurvitz, P. M., Monsivais, P. & Moudon, A. V. Obesity and supermarket access: Proximity or price? *American Journal of Public Health* vol. 102 (2012).

26. Aggarwal, A. *et al.* Access to supermarkets and fruit and vegetable consumption. *Am. J. Public Health* 104, 917–923 (2014).

27. Chastre, C., Duffield, A., Kindness, H., Lejeune, S. & Taylor, A. *The Minimum Cost of a Healthy Diet - Findings from piloting a new methodology in four study locations*. (2007).

28. Dizon, F., Herforth, A. & Wang, Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security* 21, 38–51 (2019).

29. Fao, Ifad, Unicef, Wfp & Who. *The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets*. https://doi.org/10.4060/ca9692en (2020) doi:10.4060/ca9692en.

30. Brinkman, H.-J., de Pee, S., Sanogo, I., Subran, L. & Bloem, M. W. High Food Prices and the Global Financial Crisis Have Reduced Access to Nutritious Food and Worsened Nutritional Status and Health. *J. Nutr.* 140, 153S-161S (2010).

31. Hoddinott, J. & Yohannes, Y. *Dietary Diversity as a Food Security Indicator, FCND Discussion Paper No. 136*. (2002).

32. Headey, D. D. & Alderman, H. H. The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents. *J. Nutr.* (2019) doi:10.1093/jn/nxz158.

33. Darmon, N. & Drewnowski, A. Contribution of food prices and diet cost to socioeconomic disparities in diet quality and health: A systematic review and analysis. *Nutr. Rev.* 73, 643–660 (2015).

34. Reardon, T., Timmer, C. P., Barrett, C. B. & Berdegué, J. The Rise of Supermarkets in Africa, Asia, and Latin America. *Am. J. Agric. Econ.* 85, 1140–1146 (2003).

35. Gómez, M. I. & Ricketts, K. D. Food value chain transformations in developing countries: Selected hypotheses on nutritional implications. *Food Policy* 42, 139–150 (2013).

36. Wiggins, S. *et al. The rising cost of a healthy diet: Changing relative prices of foods in high-income and emerging economies*. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9580.pdf (2015).

37. Green, R. *et al.* The effect of rising food prices on food consumption: systematic review with meta-regression. *BMJ* 346, f3703 (2013).

38. Cornelsen, L. *et al.* What Happens to Patterns of Food Consumption when Food Prices Change? Evidence from A Systematic Review and Meta-Analysis of Food Price Elasticities Globally. *Health Econ.* 24, 1548–1559 (2015).

39. Bouis, H. E., Eozenou, P. & Rahman, A. Food prices, household income, and resource allocation: Socioeconomic perspectives on their effects on dietary quality and nutritional status. *Food Nutr. Bull.* 32, S14–S23 (2011).

40. Miller, V. *et al.* Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet. Global health* 4, e695-703 (2016).

41. Herforth, A. & Masters, W. A. *Indicators and Tools for the Cost of Nutritious Diets*. https://sites.tufts.edu/candasa/ (2019).

42. Herforth, A. *et al. Background paper for The State of Food Security and Nutrition in the World 2020*. (2020).

43. Gaddis, I. *Prices for Poverty Analysis in Africa*. http://dx.doi.org/10.1596/1813-9450-7652 (2016) doi:10.1596/1813-9450-7652.

44. Popkin, B. M. The nutrition transition and obesity in the developing world. *J. Nutr.* 131, 871S-873S (2001).

45. Kennedy, E. T. The global face of nutrition: what can governments and industry do? *J. Nutr.* 135, 913–915 (2005).

46. Doak, C. M., Adair, L. S., Bentley, M., Monteiro, C. & Popkin, B. M. The dual burden household and the nutrition transition paradox. *Int. J. Obes.* 29, 129–136 (2005).

47. Unicef, Who & World Bank. *Joint child malnutrition estimates - Levels and trends*. https://www.who.int/nutgrowthdb/estimates2017/en/ (2018).

48. Who. *Prevalence of anaemia in women - Estimates by country*. http://apps.who.int/gho/data/view.main.GSWCAH28v (2017).

49. Jayatissa, R., Gunathilaka, M. M. & Fernando, D. N. *Sri Lanka National Nutrition and Micronutrient Survey 2012*. (2012).

50. NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: A pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* 387, 1377–1396 (2016).

51. Popkin, B. M. Urbanization, lifestyle changes and the nutrition transition. *World Dev.* 27, 1905–1916 (1999).

52. NCD Risk Factor Collaboration. Rising rural body-mass index is the main driver of the global obesity epidemic in adults. *Nature* 569, 260–264 (2019).

53. Torheim, L. E. & Arimond, M. Diet Quality, Micronutrient Intakes and Economic Vulnerability of Women. in *Diet Quality: An Evidence-Based Approach, Vol. I* (eds. Preedy, V. R., Hunter, L. A. & Patel, V. B.) 105–115 (Springer, 2013).

54. Jayatissa, R. *et al. National Nutrition and Micronutrient Survey of Pregnant Women in Sri Lanka 2015*. (2017).

55. WHO. *Non Communicable Disease Risk Factors: STEPS Fact Sheet Sri Lanka 2015*. (2015).

56. Jayawardena, R., Byrne, N. M., Soares, M. J., Katulanda, P. & Hills, A. P. Food consumption of Sri Lankan adults: an appraisal of serving characteristics. *Public Health Nutr.* 16, 1–6 (2012).

57. Reardon, T., Timmer, C. P. & Minten, B. Supermarket revolution in Asia and emerging development strategies to include small farmers. *PNAS* 109, 12332–12337 (2012).

58. Liyanage, N. V. R. Behind the curtains of pola: Creating and negotiating local markets in Sri Lanka. (Ball State University, 2016).

59. Fitch Ratings. *Spotlight: Sri Lankan Modern Grocery*. https://lmd.lk/wp-content/uploads/2017/11/Spotlight-Sri-Lankas-modern-grocery-retail-Nov-2017.pdf (2017).

60. Reardon, T. & Gulati, A. *The Rise of Supermarkets and Their Development Implications: International Experience Relevant for India. IFPRI Discussion Paper 00752*. (2008).

61. WFP. *Sri Lanka National Strategic Review of Food Security and Nutrition: Toward Zero Hunger*. (2017).

62. Townsend, N. *et al.* Barriers to healthy dietary choice amongst students in Sri Lanka as perceived by school principals and staff. *Health Promotion International* 32, 91–101 (2017).

63. World Bank. *Socio-Economic Assessment of the Conflict Affected Northern and Eastern Provinces*. (2018).

64. Provincial Planning Secretariat. *Five Year Investment Programme (2009-2013) Northern Province*. (2009).

65. WFP and HARTI. *Sri Lanka Food Security Atlas: Livelihoods, Food Security, and Resilience*. (2015).

66. Department of Census and Statistics. *Household Income and Expenditure Survey, 2016*. (2018).

67. Dizon, F. & Herforth, A. *The Cost of Nutritious Food in South Asia. Policy Research Working Paper 8557*. http://www.worldbank.org/research. (2018).

68. World Bank. Poverty and Equity Data: South Asia. *Poverty and Equity Data Portal* (2022).

69. Downs, S. M., Ahmed, S., Fanzo, J. & Herforth, A. Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets. *Foods* 9, (2020).

70. Ruel, M. T., Alderman, H. & Maternal and Child Nutrition Study Group. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *Lancet* 382, 536–551 (2013).

71. Barrett, C. B. Smallholder market participation: Concepts and evidence from eastern and southern Africa. *Food Policy* 33, 299–317 (2007).

72. Sibhatu, K. T. & Qaim, M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 77, 1–18 (2018).

73. Ruel, M. T., Quisumbing, A. R. & Balagamwala, M. Nutrition-sensitive agriculture: What have we learned so far? *Global Food Security* 17, 128–153 (2018).

74. Sibhatu, K. T. & Qaim, M. Rural food security, subsistence agriculture, and seasonality. *PLoS One* 12, e0186406 (2017).

75. Snapp, S. S. & Fisher, M. “Filling the maize basket” supports crop diversity and quality of household diet in Malawi. *Food Security* 7, 83–96 (2015).

76. FAO and the World Bank. *Dry Zone of Sri Lanka: Climate-Smart Intensification of Upland and Lowland Crop Production Systems*. https://www.fao.org/documents/card/en/c/cb8394en (2022) doi:10.4060/cb8394en.

77. Gilbert, C. L., Christiaensen, L. & Kaminski, J. Food price seasonality in Africa: Measurement and extent. *Food Policy* 67, 119–132 (2017).

78. Schneider, K., Christiaensen, L., Webb, P. & Masters, W. A. *Assessing the Affordability of Nutrient-Adequate Diets*. https://openknowledge.worldbank.org/handle/10986/36485 (2021).

79. Coslet, C., Goodbody, S. & Guccione, C. *FAO/WFP Crop and Food Security Assessment Mission to Sri Lanka*. (2017).

80. Ministry of Disaster Management & Wfp. *Sri Lanka Drought Impact Assessment and Monitoring using Computer Assisted Telephone Interviewing (CATI) Services*. (2017).

81. Swinnen, J. & McDermott, J. COVID-19: Assessing impacts and policy responses for food and nutrition security. in *COVID-19 and Global Food Security* (eds. Swinnen, J. & McDermott, J.) 8–12 (International Food Policy Research Institute).

82. Carducci, B. *et al.* Food systems, diets and nutrition in the wake of COVID-19. *Nature Food* 2, 68–70 (2021).

83. Béné, C. *et al. Impacts of COVID-19 on People's Food Security: Foundations for a more Resilient Food System*. (2021).

84. Bogmans, C., Pescatori, A. & Prifti, E. Four Facts about Soaring Consumer Food Prices. *IMFBlog* https://blogs.imf.org/2021/06/24/four-facts-about-soaring-consumer-food-prices/ (2021).

85. United Nations Secretary General. *Policy Brief: The Impact of COVID-19 on Food Security and Nutrition*. https://unsdg.un.org/resources/policy-brief-impact-covid-19-food-security-and-nutrition (2020).

86. United Nations Secretary General. *Policy Brief: The Impact of COVID-19 on Women*. https://unsdg.un.org/resources/policy-brief-impact-covid-19-women (2020).

87. Weerahewa, J., Hemachandra, D. & Roy, D. How agri-food chains in Sri Lanka fared during the stringent COVID-19 control measures? *IFPRI South Asia* https://southasia.ifpri.info/2020/05/13/how-agri-food-chains-in-sri-lanka-fared-during-the-stringent-covid-19-control-measures/ (2020).

88. Galappattige, A. & Wallace, M. *COVID-19 and food and agriculture in Sri Lanka - update on impact of lock down March 20*. (2020).

89. Rathnayake, S., Gray, D., Reid, J. & Ramilan, T. The impacts of the COVID-19 shock on sustainability and farmer livelihoods in Sri Lanka. *Current Research in Environmental Sustainability* 4, 100131 (2022).

90. Singh, N. *et al.* Food Insecurity Among Farmers in Rural Sri Lanka and the Perceived Impacts of COVID-19. *Current Developments in Nutrition* 5, 248–248 (2021).

91. UNICEF. *COVID-19 Household Impact: Sri Lanka Telephone Survey Round 1*. https://www.unicef.org/srilanka/reports/covid-19-crisis-household-impact (2020).

92. Johns Hopkins Center for Systems Science and Engineering. COVID-19 Dashboard. *Johns Hopkins University Coronavirus Resource Center* https://coronavirus.jhu.edu/map.html (2022).

93. Thowfeek, R. Sri Lanka’s dilemma: Pay off debt or pay for milk, meds and gas. *Al Jazeera* (2022).

94. Aneez, S. As food and energy prices soar, Sri Lankans go without. *Al Jazeera* (2021).

95. News Agencies. Sri Lanka allows sharp rise in food prices to ease shortages. *Al Jazeera* (2021).

96. Verité Research releases results of island-wide farmers’ survey on fertiliser ban. *Verité Research* https://www.veriteresearch.org/2021/08/25/verite-research-releases-results-of-island-wide-farmers-survey-on-fertiliser-ban/ (2021).

97. Wipulasena, A. & Mashal, M. Sri Lanka’s Plunge Into Organic Farming Brings Disaster. *The New York Times* (2021).

98. Arudpragasam, A. Analysis: How to End Sri Lanka’s Food Crisis. *Foreign Policy* (2021).

Chapter 3. Study design and methodology

Overview and conceptual framework

This study took place in 45 Grama Niladhari (GN) Divisions spread across 5 rural districts of Sri Lanka: Batticaloa, Mannar, Matale, Monaragala, and Mullaitivu. These districts, while located in northern, central, eastern, and southern provinces of the country, were all contained within Sri Lanka's agro-ecological dry zone. The study GNs were contained within one Divisional Secretary (DS) Division in each district[g]. These areas participated in WFP's R5N program, which had the objectives of: strengthening the resilience of smallholder farming households by enhancing their capacity to cope with recurrent climate shocks; and improving diet quality of household members.

To assess the effectiveness of the R5N program in achieving these objectives, an impact evaluation was carried out by IFPRI, in partnership with the Medical Research Institute of Sri Lanka and Wayamba University. That impact evaluation, consisting of three surveys in December 2020, July 2021, and December 2021, utilized phone interviews to assess household and individual respondent level-characteristics and outcomes, including diet quality.

The present study had the goal of assessing rural food environments in Sri Lanka and their influence on diet quality and was implemented as a sub-study within the R5N impact evaluation. As mentioned in the previous section, this structure enabled the generation of evidence that could contribute to epidemiological questions around the measurement of food environments and the association between these exposures and diets, in addition to contextual evidence to inform the evaluation of the R5N program. The R5N food environment sub-study carried out in-person surveys in markets and retail shops in the 45 participating GN Divisions beginning in December 2020. Though the intention was to conduct monthly follow-ups, Covid-19

[g] A DS Division is an administrative sub-unit of the district, and GN Divisions are the lowest administrative units in Sri Lanka, each comprising on average 3 to 7 villages.

restrictions resulted in a total of only ten follow-ups between December 2020 and December 2021.

The framework presented in **Figure 3.1** illustrates the specific aims of the R5N food environment sub-study, in the context of many of the relationships described in the literature review. The first aim consisted of a descriptive analysis of food environments in the R5N study area at baseline (December 2020). The dimensions of the food environment included in this aim were the cost and availability of food in local traditional markets and retail shops – highlighted in the green outlined boxes. Food costs were assessed in terms of relative costs of food groups as well as the cost of diets. Variation in cost and availability of food across the 5 study districts was also assessed, and differences between food groups. Specific hypotheses in this aim were formulated based on the hypothesis that food prices may differ across the 5 districts to a greater extent than food availability. Also, within a single district, due to the limited geographic range of the study area (consisting of only 1 DS Division) and the sharing of markets across multiple study GNs, large variation in prices and availability was not expected.

Though it was originally intended to include households' physical access to traditional markets and retail shops in the first aim descriptive analysis as well, this became infeasible due to changes in the study brought on by Covid-19; when the household questionnaire was adapted for phone interviews, it was no longer possible to gather geospatial data for households in the study, thus eliminating options for estimating variables such as the distance to nearest traditional markets, or density of retail outlets surrounding a household.

The second aim explored the change in the cost and availability of food over the course of the study period, from December 2020 to December 2021. It was originally intended for this analysis to allow conclusions to be made about the effect of seasonality on food environments in the study area; however, extraordinary shocks took place leading up to December 2020 and into 2021—first Covid-19 and then Sri Lanka's foreign exchange crisis—which disrupted typical seasonal patterns in food prices. To address this limitation, additional analysis was conducted using secondary data accessed from Sri Lanka's national food price surveillance system, managed by the Hector Kobbekaduwa Research and Training Institute (HARTI), for the time period of January 2014 through December 2021. Within this national dataset, it was possible to: a) estimate a typical seasonal pattern in the cost of a healthy diet; and b) compare this pattern to the shape and trend of the cost of a healthy diet during Covid-19. For the study period from December 2020 to December 2021, it was also possible to compare trends in the R5N area to these national trends.

The third aim explored associations between food environment exposures—including food availability and the cost of a healthy diet—and dietary diversity. This aim merged the food environment data from traditional markets and retail shops with the household and diet data gathered as part of the R5N impact evaluation study. Though it was intended as a sub-aim to assess whether crop production diversity modified these associations (and in so doing, contribute to the expanding evidence base on crop diversity and dietary diversity linkages), this analysis was limited by changes implemented due to Covid-19; the shorter questionnaire adapted for phone interviews meant that it was no longer possible to systematically assess all of the crops produced by a study participant. Additionally, as previously mentioned, associations between food environment exposures and dietary diversity were only assessed at baseline, and therefore did not examine effect measure modification with program participation, though this will be a focus of later analysis.

Specific aims and hypotheses

Aim 1: To characterize the food environment in study GNs at baseline in terms of food availability, and the cost and affordability of a healthy diet.

Hypothesis 1.1: The diversity of foods available will exhibit a low coefficient of variation across study GNs, with limited clustering by district.

Hypothesis 1.2: The cost of a healthy diet will vary across study GNs by average household income, distance to nearest population centers, and will demonstrate clustering by district.

Hypothesis 1.3: The relative cost of nutrient-dense foods will be higher than the relative cost of ultra-processed foods.

Aim 2: To measure changes in the food environment in study GNs over time, in terms of food availability and the cost of a healthy diet, and compare these changes to national averages, as well as the magnitude of changes during years prior to Covid-19.

Hypothesis 2.1: The diversity of foods available will become more constrained in the second half of 2021 in study GNs and as the foreign exchange crisis increased in severity.

Hypothesis 2.2: The cost of a healthy diet will increase in the second half of 2021 in the study GNs and as the foreign exchange crisis increased in severity.

Hypothesis 2.3: The cost of a healthy diet will experience a larger increase in the study GNs in the R5N relative to the national average.

Hypothesis 2.4: Covid-19 and the foreign exchange crisis will result in greater seasonal variation in the cost of a healthy diet compared to a typical year, as well as a greater trend increase.

Aim 3: To test associations between food environment characteristics, including food availability and the cost of a healthy diet, and dietary diversity of adults in study communities.

Hypothesis 3.1: The cost of a healthy diet in study GNs will be inversely associated with dietary diversity

Hypothesis 3.2: The diversity of foods available in study GNs will be positively associated with dietary diversity.

Study setting

The setting for the impact evaluation and food environment sub-study was determined based on the targeting of WFP's R5N program. With the program's focus on building resilience to climate shocks among smallholder farmers. This targeting was carried out jointly by WFP and the Government of Sri Lanka. It firstly took into consideration geographic vulnerability to droughts and floods, which are the key climate-related causes of lost income among farmers. The five participating districts—Batticaloa, Mannar, Matale, Monaragala, and Mulliativu—are all located in the agro-ecological dry zone of Sri Lanka and are subject to frequent droughts and floods. They were also chosen to represent different geographic areas of the country. See **Figure 3.2**, a map of the study area.

Livelihoods in the study areas are largely dependent on paddy rice, with yields limited by access to training and technology, as well as water availability. Many smallholders grow rice only during the primary rainy season (*maha*) and during the secondary season (*yala*), grow less water-intensive lowland vegetables or other field crops (e.g. chili, onion, potatoes, legumes). Other field crops are especially common in Monaragala, which is more dependent on rainfed agriculture due to historically limited irrigation infrastructure, however damaged irrigation infrastructure from the civil war also limits water access in the northern districts of Mannar and Mullaitivu[1]. Many households also own livestock or engage in inland fishing, though these are mainly to supplement household consumption, not major commercial activities.

Districts chosen for the R5N program were also based on their poverty levels, vulnerability to child malnutrition, and food insecurity. Around 20% of the populations in Batticaloa, Matale, and Monaragala are living below the national poverty line, while in Mullaitivu 45% of the population is below the national poverty line, the highest in the country[2]. Though Mannar has a poverty headcount of only 8% (below the national average of 14%), pockets of poverty remain in former conflict-affected areas. Mannar and Batticaloa have among the highest prevalences of child stunting in the country (21% of children under five years of age each) and

Monaragala and Mullaitivu are the two districts with the highest prevalences of child wasting (25% and 22% of children under five years of age, respectively)[3]. While no district-level estimates of food insecurity prevalences were available, previous cost of diet assessments conducted by WFP indicated high levels of unaffordability in these five districts, especially relative to urban areas along the western and southern coasts[4,5].

In each district, WFP and the Government selected one DS Division to target the R5N program to, again based on poverty, malnutrition, and food insecurity. A needs assessment was also conducted to identify DS Divisions that would benefit from rehabilitation of water-related irrigation infrastructure. Mannar and Mullaitivu especially had market and agricultural infrastructure that had sustained heavy damage during the civil war. A similar targeting criteria was further utilized to select individual GN Divisions within each DS Division, with the added requirement that they minimize overlap with other development initiatives carried out by other partners.

The R5N program

Food assistance for assets (FFA) programs like R5N are one of WFP's key smallholder-facing initiatives that aim to fight hunger and food insecurity. FFA programs are context-specific and usually include a package of interventions, though their two principal components are typically the following: 1) a food or cash transfer that is provided to beneficiaries in exchange for the labor they provide in building or renovating assets, which may help to satisfy short-term food needs; and 2) the community and household-level assets themselves, which are meant to stabilize ecosystems and strengthen livelihoods, thus protecting the longer-term food security and of beneficiaries[6]. Depending on the needs of local communities and objectives of individual programs, FFA interventions may also incorporate trainings that aim to enhance agricultural or business skills. They may also include nutrition-specific activities, such as the inclusion of behavior change communication (BCC), or women's empowerment activities.

In dry zones like the R5N context in Sri Lanka, the asset component of FFA programs often focuses on enhancing water availability for agriculture, through achievement of rainfall multiplier effects generated by linking larger-scale watershed rehabilitation measures (e.g. community reservoirs and irrigation channels) with smaller-scale household measures (e.g. agro-wells and farm ponds). These rehabilitation activities may also help to prevent soil erosion.

The irrigation-related assets included in the R5N project varied by GN according to the availability of existing, but malfunctioning infrastructure. WFP and the Government worked with community members to identify and prioritize assets, then rehabilitation work was carried out by the program beneficiaries under the technical supervision of the Government. During the time that beneficiaries were working on the assets, they received a cash transfer from WFP that was set at an amount that would fill existing gaps in household food needs, but is not so high that it would draw labor away from formal markets or distort wages.

In addition to the community-level (reservoirs, dams, and channels) and household-level (ponds and wells) assets, beneficiaries were provided with training on proper maintenance of assets and minor irrigation systems as well as on diversified agricultural livelihood activities. These livelihood activities commonly included aquaculture (for which irrigation reservoirs and ponds served a dual purpose), gardening, crop diversification, and small livestock rearing.

Since 2017, WFP has been rolling out guidance for nutrition-sensitive programs, which details opportunities for improving the contribution of all program modalities (including FFA) to nutrition[7]. During the design stages of the R5N program, WFP realized that there was potential make it more nutrition-sensitive through the addition of an education component that would aim to improve diet quality, in combination with the increased income and enhanced resilience outcomes that were expected from the other program activities. This education component consisted of a health promotion process (HPP) implemented by the Foundation for Health Promotion (FHP), which WFP partnered with. The HPP activity was a community-driven, participatory behavior change approach in which FHP facilitators initiated dialogues with community members that were used to identify health-related topics of importance and the underlying causes of health problems (including diet quality). From these dialogues, health-related messages and tools were developed (e.g. kitchen calendars and containers to measure sugar, salt, and oil). In HPP, community members also set up their own processes to address the problems and causes identified and were provided with training on how to continually monitor their progress. HPP topics in the R5N program included diet quality, cash management, women's decision-making, healthy lifestyles, among others.

Though there were some initially some delays in the implementation schedule of R5N activities due to Covid-19, these activities were eventually permitted to be undertaken as planned, as all agriculture related work was declared an essential service in Sri Lanka. The HPP behavior change activities were likewise able to move forward, but during some months, group phone calls or WhatsApp group messages needed to replace in-person dialogues between FHP facilitators and communities.

The R5N impact evaluation

The R5N evaluation was carried out among 1,369 households across the 45 study GNs to detect impacts of the R5N program, as well as the combined R5N + HPP package, on WFP's intended outcomes. The primary outcomes evaluated were dietary diversity and an overall diet quality score at the individual-level, and household consumption and expenditure at the household-level, which were proxy measures for household income. WFP's basic theory of change was that the rehabilitated community and household irrigation asset base would enhance water availability, which, in combination with training and diversified livelihood activities would enable households to increase agricultural productivity, and then household income. Furthermore, this increased household income, along with the HPP intervention, would improve diet outcomes.

The evaluation used a longitudinal, household and GN-matched, control trial design. There were already 30 GNs that had been selected by WFP and the Government to receive the R5N program. Of these, 15 were randomly selected to receive the addition of the HPP intervention. Then, 15 control GNs were selected based on a community matching process to ensure similar socioeconomic characteristics. The evaluation therefore sought to compare outcomes across the following three study arms:

1. 15 GN Divisions that received the R5N program;
2. 15 GN Divisions that received the R5N program and the HPP intervention (i.e. the nutrition-sensitive design); and
3. 15 GN divisions that were controls.

To further enhance comparability between treatment and control groups, matching was also implemented at the household level, using a nearest neighbor method in which beneficiary households in the two treatment groups were matched to one or more non-beneficiary households in the control group on pre-intervention characteristics.

The baseline survey took place between December 2020 and February 2021, with a midline survey occurring in May-July 2021, and an endline survey in December 2021-February 2022. Phone surveys included an individual-level 24-hour dietary recall and modules on household level consumption, demographics, program exposure, nutrition knowledge, food security, agriculture activities, and experiences related to Covid-19.

As described previously, various changes had to be implemented due to Covid-19 restrictions. First, it was necessary to delay the beginning of the evaluation from May 2020 to December 2020. WFP implemented the R5N program in three phases, with different GNs starting implementation in 2019, 2020, and 2021. Due to the need to wait for the Government to approve the initiation of the evaluation and the additional challenge of training enumerators remotely as opposed to in-person, the evaluation was conducted among the final phase of the program (those GNs beginning implementation in 2021) as opposed the second.

Second, the household survey was adapted for phone interviewing and spread out over multiple calls, each lasting 25 minutes or less and including a different set of modules. This still required substantial shortening of the interview, and agriculture and household expenditure modules were especially limited. For example, in the agriculture module, as opposed to systematically assessing each crop that the household produced, the data collection was limited to only the three most important crops for the household.

Table 3.1 provides an overview of the roles and responsibilities of the R5N impact evaluation and food environment sub-study partners.

Study population, sampling and recruitment

Traditional markets and village retail shops

Though a variety of other retail food outlet types exist in rural Sri Lanka—including streetside vendors and mobile vendors—this study implemented surveys only in traditional food markets and village retail shops. Traditional food markets, also known as ‘pola’ in Sinhalese or ‘santhai’ in Tamil, are open-air markets that typically operate only once or twice a week, bringing together vendors of fresh and dry foods. These markets are preferred by rural consumers due to their perceived lower prices and freshness in comparison with other outlets[8]. In contrast, village retail shops focus on dry and processed foods and are more densely located throughout communities, though in some remote areas, only a few small shops may operate and are typically extensions of residential homes. Weekly grocery shopping is typically done in the traditional, open-air markets, which also serve as social and cultural centers in rural communities, though village retail shops may be used in cases of emergency, if a food runs out, or for spontaneous purchases[9]. Foods sold in traditional markets are typically through professional vendors who source from wholesale markets, though one study in five districts of Sri Lanka found that farmers selling their own production made up 10% of the vendors in traditional markets. These farmers also supplemented their offerings with neighbors' production, as well as foods from wholesale markets[10].

There were no published lists of traditional markets and village retail shops that could be accessed for a sampling frame. For this reason, a purposive sampling approach was used to select traditional markets and retail shops for inclusion in the study. This relied on input from local stakeholders who acted as key informants, including WFP field officers based in each of the five districts and village leaders in each of the GNs. For the market sample, the two closest, most frequently used traditional markets used by households in each of the 45 study GNs were identified. There was no requirement for markets to be located within the GN's administrative boundaries. Study areas were contained within a relatively small section of each district (a DS Division), so in most cases, markets included in the sample were utilized by multiple study GNs. Village leaders also indicated the names and locations of the three most frequented village retail shops within each study GN. In a few cases, less than three shops operated in GN, while in others, thirty or more shops were in operation. The goal of sampling three retail shops per GN was in consideration to budget and time constraints of enumerators, not based on representativeness. Resource and time constraints also guided the decision not to survey lesser utilized vendor types, such as streetside and mobile vendors, though mobile vendors in particular may have taken on more importance in the context of Covid-19 restrictions.

For the purposes of this study, each GN's food environment was defined as the two traditional markets closest to it and the retail shops sampled within its boundaries, which was typically three shops but in a few cases, only one or two. The decision to include two markets in each GN's food environment was made based on the varying size of markets, their operation on different days of the week, and inputs from village leaders indicating that households may not use one traditional market exclusively. To check the sensitivity of food availability and diet cost estimates to this definition of the food environment, separate availability and cost estimates were also made for GN-level food environments comprised of only the single closest traditional market (yet still including the village retail shops).

Enumerators verified the locations of each traditional market and village retail shop identified by the GN village leaders. This also provided an opportunity to check if the shops were still in operation and that owners were willing to allow their shops to be included in the data collection. Since the market and retail shop surveys involved auditing stalls and shops and interviewing vendors and owners about their trade, and did not gather any personal information about the vendors or owners themselves, a formal consent process was not utilized. However, vendors and shop owners were all asked if they would like to participate, explained the purpose of the study, the research partners, how long the data collection would last, and what it would entail. Permission was also granted by local DS Division authorities for the food environment research to be conducted and letters of approval were carried by enumerators during the initial and subsequent data collection visits, which were shown to vendors and shop owners who had concerns about local approval. Any vendors or shop owners that did not want to participate were replaced with another retail shop or market stall, assuming a replacement was available.

Traditional open-air markets in Sri Lanka typically feature multiple vendors of each food category. The largest markets may include over 100 vendors, while smaller markets may have less than 10. Enumerators were provided additional guidance on the sampling of vendors within markets. This guidance is included in **Appendix 1.1.** Enumerators attempted gather three price observations for each food item, sampling vendors from different locations with the markets (i.e. front, back, and middle), of different sizes (i.e. including vendors offering a large number of items for sale as well as vendors offering a smaller number of items), selling average quality items (not damaged), and selling the varieties of food items that were most widely available.

R5N Impact Evaluation study participants

Baseline data from dietary and household surveys was utilized for the first aim of this dissertation, to assess the affordability of a healthy diet relative to household food expenditure, as well third aim, examining the association between food environment exposures and diet outcomes. These surveys were led IFPRI and data was shared for use in this food environment sub-study. Sampling and survey procedures for the impact evaluation were adapted due to restrictions imposed by Covid-19 in 2020, requiring that the household and diet surveys be conducted through phone interviews. All R5N and health promotion beneficiaries in the 30 treatment GNs were contacted using beneficiary lists with phone numbers that were provided to IFPRI by WFP. Households in the 15 control GNs were randomly selected from the most recent electoral lists (from 2016), using population-based sampling. The only exclusion criteria imposed were for households that were not engaged in agricultural activities, and individuals that were less than 18 years of age. Interviews were conducted with the household member that was enrolled in the WFP intervention in the case of the treatment arms, while in the control arm, enumerators identified the household member that was most involved in agricultural activities. Prior to beginning data collection, enumerators read an informed consent statement and proceeded with interviews among participants who verbally consented to participate. Sample size

Data collection

Traditional markets and village retail shop data collection

Separate questionnaires were developed for traditional markets and retail shops and programmed for mobile data collection using the SurveyCTO platform. The market questionnaire is included in **Appendix 1.2** and the retail shop questionnaire is included in **Appendix 1.3**. Both questionnaires assessed background characteristics and features of the market or shop (e.g. size of shop or market, days and hours of operation, type of covering, availability of electricity and refrigeration, type of road access). The main component of each questionnaire was an audit of the availability and prices of a pre-defined food list. Where prices were not visibly displayed, enumerators interviewed shop owners or vendors. Food items included in the food list were identified using the Sri Lanka Household Income and Expenditure Survey 2016, which listed foods purchased by households, and the food list adopted by the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), the primary government agency responsible for collecting and analyzing agricultural market information[11]. The Household Income and Expenditure Survey

The differences between the questionnaires were the following: the market questionnaire required enumerators to collect three different price observations for each food item, to account for the multiple vendors available, while only one observation was required for retail shops; and the retail shop questionnaire included an extended list of packaged a processed foods, to account for their relative focus on those product categories (though only availability was assessed for these items and not prices). A full list of the foods included in both questionnaires is included in **Annex 1.4.** For two categories of ultra-processed foods and beverages—biscuits and sugar-sweetened beverages—enumerators also entered the total number of different products available in the shop. These are two of the most common processed food categories found in Sri Lankan retail outlets and collecting information on the total number of items was an attempt to assess the extent of their physical footprint relative to other foods. One way this has been done in other food environment research is by measuring the percentage of shelf space dedicated to specific types of food, but it was determined that measuring this would have placed too much burden on enumerators[12].

Enumerators based in the study areas were recruited from the University of Peradeniya Faculty of Agriculture and underwent training in November 2020. Training topics included the study questionnaires, use of tablets and the SurveyCTO app, as well as recommended methods for collection of food prices, the latter of which was led by HARTI. A pilot testing was conducted in November, which also allowed enumerators to verify the retail shop and market locations.

Data supervisors based at the University of Peradeniya provided feedback to enumerators based on the pilot testing results to improve accuracy and consistency across enumerators. A question-by-question survey manual was also developed and shared with enumerators **Annex 1.5.**

Data collection for the food environment sub-study took place on a monthly basis between December 2020 and December 2021, with enumerators attempting to visit the same retail shops and markets each month. However, the study area was affected by market closures and curfews that took place as a result of the rise in Covid-19 cases during the summer 2021, which prevented data collection during May, June, and August. Excluding these months, a total of nine time points were included in the study. However, not all markets and retail shops could be surveyed for each follow-up period. For example, both of the traditional markets sampled in the district of Monaragala were closed from September to November 2021 due to a localized Covid-19 outbreak. Village retail shops across the study area were occasionally closed on the days when enumerators attempted to visit them. Aside from the baseline data collection, the retail shops were not replaced with another outlet and the results are based only on the remaining retail shops and markets that could be reached during that month. Monthly data collection visits by enumerators were tracked by a data supervisor based at the University of Peradeniya, noting the date of data collection, the name of the enumerator, and if it was not possible to collect data, the reason why. Data collection visits were typically planned for the last week of each month, though in some cases, due to Covid-19 restrictions, needed to be extended another week.

R5N Impact Evaluation study participant data collection

The household survey was divided into three separate phone calls, each lasting around 25 minutes, which assessed household demographics, expenditures (food and non-food), household assets, food security, agriculture, among other characteristics. Expenditure data was collected as a proxy measure of household income. Food expenditure was assessed for a pre-defined list of 135 items, with participants reporting the quantity of each item consumed over the previous 7 days. These quantities were then linked with price data from market surveys to estimate expenditure. Non-food expenditures were reported as the quantity of expenditure on a standardized list of items and services (e.g. health and education) over the previous 30 days. Food security was assessed using the Food Insecurity Experience Scale (FIES), which is a series of eight questions about a respondent (or a respondent's household) experiences related to access to adequate food[13]. In the R5N household survey, FIES was implemented with respect to the entire household and used a recall period of the previous 30 days. Agriculture data collected included the size of agricultural land holdings, agricultural earnings over the previous year, and more detailed information about planting and harvesting activities for the household's four most important crops.

Dietary surveys consisted of an open 24-hour dietary recall that utilized three passes. In the first pass, a quick list of foods and beverages consumed the previous day was assembled. The second pass consisted of a description of each food and the portion size consumed. The third pass was a final check to ensure that no items were left out. Due to the need to keep phone interviews short, in lieu of collecting recipe information for mixed dishes during the interview, a database of standard recipes was compiled. Portion size estimates were based on locally used utensils and food piece types, sizes, or counts, which the respondent selected verbally. Dietary surveys were conducted among the same household member participating in the household survey.

Data management

Data from the market and retail shop surveys was stored on the SurveyCTO platform, where it was downloaded and saved to DropBox on a monthly basis by the data supervisor, who performed data cleaning. This involved flagging incorrect or implausible food item units, outlier prices, as well as missing data for items that should normally be available. In these cases, the data supervisor would communicate with enumerators via a Whatsapp group that was set up for the study. In some cases, enumerators would return to the market or retail shop to verify availability or prices. Cleaned datasets were then transferred to a folder on JHU OneDrive for analysis purposes. Additional data checks and cleaning were conducted in Stata.

Data from the household and dietary surveys were managed and stored by IFPRI in accordance with protocols approved by the Institutional Review Board (IRB) of IFPRI and the Ethics Review Committee of Wayamba University of Sri Lanka.

Variable Creation

Food environment measures

Food availability

Food availability was assessed for each food group, both as a binary variable (0: no items available from the group; 1: at least one item available from the group) and as a continuous variable, including the count of unique items that were available. For the continuous variable, the maximum possible was 175 food items. This count did not include duplicate items, such as different varieties of rice or mangos, however, different processing methods of the same fish species (fresh/unprocessed, dried, or canned) were counted as different food items, as was rice in flour or noodle form versus raw rice. Finally, the ability to source sufficiently diverse items to meet the variety criteria suggested in Sri Lanka's FBDG and adapted from a previous study of the cost of healthy diets in the South Asia region was assessed, again as a binary variable[14]. These variety criteria are provided for the size food groups included in the FBDG and are detailed in **Table 3.2**. Each of these three availability measures was assessed at the individual outlet level, in both retail shops and traditional markets, as well at the GN-level. All three measures are utilized in *Chapter 4* and 5, however, for *Chapter 6*, which examined the associations between food availability and dietary diversity, a summary availability indicator was created, which was the total count of all unique food items available in a GN, as this was the availability measure that had the most variation at baseline.

Nutrition environment measures survey for stores (NEMS-S)

A version of the Nutrition Environment Measures Survey for Stores (NEMS-S) was adapted for the study. The NEMS-S tool has been extensively used and validated in the United States to measure food availability, food quality, and prices within retail stores, and has also been adapted in LMIC contexts, such as an urban area of Brazil, where it was integrated with the degree of food processing, based on the NOVA classification system[15,16]. Under this scoring, foods were divided into three categories, with the first representing the least processed (including unprocessed) foods and the third representing ultra-processed foods[h]. Higher points were awarded for availability of foods in the first two categories and subtracted for availability of foods in the third category.

The NEMS-S scoring sheet utilized in this study is included in **Table 3.3.** This used the model developed by *Martins et al* (2013) in Brazil as a starting point, due to the high level of specificity of the original NEMS-S tool to the United States context[16]. Further adaptations were made based on healthy and unhealthy food options in the Sri Lankan context. These included healthy options that were specifically encouraged in Sri Lanka's national FBDG, including whole wheat flour (*atta*) and pulse flours, as an occasional substitute for refined wheat and polished rice flour, and milk as a substitute for processed cheese[17]. NEMS-S scores were estimated only for retail shops, in keeping with original target of the tool. Each study GN's NEM-S estimate was calculated as the mean score of the village retail shops sampled within its boundaries. Possible

[h] For the purposes of this study "ultra-processed foods" refer to those foods wherein processing has resulted in altered nutrient content, such that unhealthy ingredients (saturated and trans fats, sugar, and salt) are disproportionately high, and fiber and micronutrients are limited. While moderately processed foods can include healthy foods, such as canned vegetables and whole grain breads, ultra-processed foods refer to energy-dense, highly processed food categories, including salty snacks, sugar-sweetened beverages, and sweets

scores ranged from -21 (maximum availability of Group 3 foods with no other foods) to 69 (maximum availability of Group 1 and 2 foods with no Group 3 foods).

Food costs: conversion to standardized unit prices

All food prices were first converted to standard units—Sri Lankan rupees (LKR) per grams or per milliliters—prior to estimation of cost of diet variables. For food items reported by vendors in non-standard units (e.g. bunches of leafy vegetables or pieces of fruit) a separate one-time data collection of weights was conducted to estimate the conversion factors. One enumerator from each district weighed the non-standard unit and the conversion factor used was the mean of all of the weights collected.

Each food item was then adjusted for non-edible portions. Sri Lanka's food composition tables were from 1979 and did not publish edible portion factors[18]. Therefore, edible portions were sourced other food composition tables that did include edible portions, including: Nepal, Bangladesh, East Asia, and the United States[19–22]. The US food composition tables were the primary source, with Nepal, Bangladesh, and East Asia used to fill in gaps for regional foods less common outside of Asia. The Aquatic Food Composition Database was used for fish and seafood items[23]. When edible portion factors were not available for specific fish species, mean values were estimated at the genus, order, or class-level, depending on availability of estimates at these different taxonomic ranks.

Cost of the recommended diet (CoRD)

CoRD was used to measure the minimum cost of adhering to Sri Lanka's national food-based dietary guidelines (FBDG), and was the primary food cost indicator used throughout the study. In Aims 1 and 2 it was a main outcome of interest, while in Aim 3 it was treated as an exposure that was tested for associations with dietary diversity. The methods used closely followed those developed as part of the Changing Access to Nutritious Diets in Africa and South Asia (CANDASA) project, described in Dizon, Herforth, and Wang (2019) and a background paper for the Food and Agriculture Organization (FAO) *State of Food Security and Nutrition in the World (SOFI)* 2020 [14,24]. Sri Lanka's FBDG indicate recommended quantities of daily servings for six food groups, including: fruits; vegetables; rice, bread, other cereals and yams (starchy staples); fish, pulses, meat and eggs (protein-rich foods); milk and other dairy; and nuts and oil. These recommendations are included in **Table 3.2.**

As a first step in estimating CoRD, food items from the market and retail shop surveys were grouped into one of the six FBDG food groups. Target serving sizes for each food group were then converted into grams. This was done using example serving sizes provided in the FBDG, for example: one serving of fruit was equal to one orange or banana; 1 serving of starchy staples was equal to 50 grams of bread or 135 grams of cooked rice; and 1 serving of protein-rich foods was equal to 15 grams of dried fish or 1 egg. Where serving size examples in the FBDG were given in non-standard units, these units were converted to grams using the same food composition tables described above. Prices per gram were then converted to prices per serving for each food item.

The minimum cost of achieving each food group recommendation was identified using the items with the lowest price per serving in each food group. However, additional requirements were utilized in food groups for which the FBDG encouraged variety. These included the following (also included in **Table 3.2)** two unique fruits were required for the fruit recommendation; two unique non-leafy vegetables and one green leafy vegetable were required for vegetables; two unique starches were required for the starchy staple recommendation; and the protein recommendation required two different types of proteins (e.g. pulse and fish, or pulse and egg). These variety requirements were similar to those utilized in the FAO *SOFI* 2020 report and explained in its associated background paper[24,25]. Lowest cost food items were identified for the food environment defined for each of the 45 GNs, meaning that all of the food items available in the two nearest markets and the retail shops sampled in each GN were first pooled together, then sorted by cost. In the case of food items with multiple varieties, such rice, which was available in parboiled form, raw form, as red or white rice, basmathi, etc., only the lowest price variety was utilized in the CoRD calculation.

The lowest cost items to meet each dietary guideline were then averaged together and multiplied by the number of servings recommended. Sri Lanka's FBDG articulate a range of servings for each food group and for this analysis, the median value of each range was used (e.g. 3 – 5 servings of vegetables were recommended, so the minimum cost of vegetables was set to 4 servings). As a final step, the six food group-minimum costs were summed together to estimate the CoRD. To assess the affordability of diet cost measures, it has been recommended to divide them by household food expenditure[24,26]. While dividing by total food and non-food household expenditure was also an option, variation in this measure across households is much more indicative of household income differences as opposed to food environment differences. In addition to estimating CoRD as a percentage of food expenditure, *Chapter 4* estimates the prevalence of unaffordability across the five districts in the study, based on the number of study participants with food expenditure less than CoRD.

In the event of market or retail shop closures during the monthly follow-ups, GN-level CoRD was estimating using the remaining sample for the GN. If there was not sufficient variety of foods to meet the requirements, CoRD was treated as infeasible (i.e. missing) for that month.

Food group relative caloric prices (RCPs)

Relative caloric prices (RCPs) measure the caloric price of a specific target food group relative to a basket of starchy staples. This can also be thought of as the cost of substituting starchy staples for different food groups, which may be a strategy for improving the micronutrient adequacy of diets in contexts like rural Sri Lanka, where undernutrition remains. RCPs were also used in the study to compare the relative costs of healthy versus unhealthy food groups, in which case, "healthy foods" were considered to be those that make up a diet in line with FBDG, while “unhealthy foods” were those that are recommended to limit. The methods constructing RCPs followed those developed by Heady and Alderman (2019)[27].

To prepare the food price data, prices were first converted to LKR per kilocalorie. This data was again sourced from available food composition tables, which typically articulate the energy content per 100 grams edible portion. In this case, it was possible to use the India food composition tables for many of the food items, which did not include edible portion coefficients, but did include food items’ energy content per 100 grams edible grams and covered a majority of items in the study’s pre-defined food lists[28]. Again, food composition tables from the United States, Nepal, and Bangladesh were used to fill in gaps where necessary.

RCPs were calculated as the ratio of three lowest caloric price items of each target food group, relative to a weighted index of starchy staples costs. Starchy staples were weighted by their availability in the national food supply, according to FAO Food Balance Sheets. The supply for each starchy staple (in kilocalories/capita/day) was sourced from FAOSTAT, which indicated that rice formed 71% of availability, wheat represented 20% of availability, and the remaining 9% was comprised of cassava, potatoes, and maize. Food items from the survey that were included in each of these starchy staple groups are identified in **Appendix 1.4.** Within each group, the median caloric price for each GN was identified, then the starchy staple index was calculated by multiplying each median value by its weight.

The numerator used in the RCP ratio was formed by taking the mean of the three lowest caloric price items in each food group. These values, in addition to the prices used in the starchy staple index, were again sorted at the GN level using the markets and retail shops that defined the food environment. RCPs were calculated for 14 food groups in order to compare relative costs between healthy and unhealthy items. However, prices for unhealthy food group categories were not part of the monthly food price data collection; these were collected at one time point, in July 2021.

Household and individual-level measures

Household food expenditure

In *Chapter 4*, household food expenditure data were used to estimate the affordability and prevalence of unaffordability among the R5N impact evaluation study population. This data was collected during the baseline household survey implemented by IFPRI, using a. Respondents were asked to report quantities of 135 pre-defined foods that their household consumed in the previous week. These data were then converted to daily per capita figures according to household size (taken from the household roster). Quantities were multiplied by average food prices from the market and retail shop data, averaged over the baseline months of December 2020, January 2021, and February 2021, to estimate expenditures. To enhance comparability between the food expenditure estimates and CoRD, non-milk beverages, sweets, condiments, and prepared foods were deducted, similar to methods used *by Dizon, Herforth, and Wang* (2019)[14]. Though this ensured that food prices for items included in the food expenditure module, which by design could not be included in CoRD, were not part of the comparison, it implies that expenditures on those categories are fixed, and unavailable to be spent on foods that make up a healthy diet as recommended in Sri Lanka's FBDG. A less conservative estimate of affordability may include food expenditure without these deductions.

Dietary diversity score

A dietary diversity score (DDS) was calculated to serve as the primary outcome in the regression analysis in *Chapter 6*, testing associations with food environment exposures. This was prepared and shared by research partners at the University of California – Davis, who led the dietary survey, in coordination Wayamba University of Sri Lanka and IFPRI. The DDS was a food group diversity measure, representing the count of unique food groups that the respondent consumed from in the previous day, and was based on ten food groups (i.e. with values ranging from 0 to 10). Foods reported in the dietary recalls were categorized into the ten mutually exclusive food groups, which matched the food groups utilized in the Minimum Dietary Diversity for Women (MDD-W) indicator[29]. These included: 1) grains, white roots and tubers, and plantains; 2) pulses; 3) nuts and seeds; 4) dairy; 5) meat, poultry, and fish; 6) eggs; 7) dark green leafy vegetables; 8) other vitamin A-rich fruits and vegetables; 9) other vegetables; and 10) other fruits. Mixed dishes reported by respondents were separated into their individual ingredients using a database of standardized recipes. Additional food groups were also tracked, but not included in the DDS, including condiments and seasonings, which was meant to better ensure that consumption of small quantities did not factor into the DDS. Exclusion of quantities less than 15 grams has been shown to increase correlation between dietary diversity scores and probability of nutrient adequacy among women[30]. In this study, the same DDS was used for men and women.

Other household-level covariates

Chapter 6 adjusted for other individual and household-level covariates, including household food insecurity and socio-economic status, which were gathered from the household survey and also required additional construction. Food insecurity was measured as a binary variable, representing whether the household had an FIES raw score of 4 or greater. Raw scores were generating by totaling the number of FIES items that a respondent reported experiencing (ranging from 0 to 8). The raw score cutoff of 4 or greater is suggested by FAO for use in regression analysis as a means of identifying households that are likely to experience moderate or severe food insecurity (versus households with raw scores of 0 to 3, which are either food secure or experiencing only mild food insecurity)[31]. This variable could only be calculated for respondents who answered all eight of the FIES items and did not skip or refuse to answer any. The SES variable was based on an index constructed by IFPRI using principal components analysis[32,33]. The following data gathered from the household survey were included in the analysis: building materials used in walls, ceiling, and floor of home; number of rooms in home; ownership of home; electricity; ownership of household appliances and valuables; ownership of vehicles; and ownership of agricultural equipment. The index was then separated into quintiles, categorizing households from 0 (least wealthy) to 5 (most wealthy).

Statistical Analysis

Aim 1: Characterizing the food environment in rural Sri Lanka

Summary statistics for the sample of traditional markets and village retail shops were first calculated and compared across the five districts in the study area using data on background characteristics and vendor properties that was collected. These statistics compared the number of markets and shops that were sampled in each district, their average size, the percentages with access to electricity and refrigeration, access to water, the type of roof covering, and the type of road access.

The principal objective of *Chapter 4* was then addressed through a descriptive analysis of the food environment in the R5N study area, using the previously mentioned food availability and food cost variables (including continuous and binary availability measures, NEMS-S, CoRD, and RCPs) and comparing summary statistics for these between the five districts, with baseline data from December 2020. This was intended to assess geographic variation over the study area and also to reveal any pre-existing differences in the quality food environments—in terms of availability, cost, and affordability— that could influence the effectiveness of WFP's R5N intervention in the different areas it was to be implemented.

Chapter 4 also examined the sensitivity of food availability and cost measures to the food environment definition originally used for each GN, which included the two traditional markets that were closest and most frequently used to it, in addition to the retail shops surveyed within its boundaries. The same measures were calculated again, only restricting GN food environments to the single nearest traditional market (while retaining the same village retail shops). Availability and cost measures were then compared between the full definition of the food environment and the restricted definition. This allowed conclusions to be drawn about the potential advantage to be drawn by households residing in each GN from ‘shopping around’, or utilizing multiple markets. These advantages could be in the form of a wider diversity of food items available, which may better contribute to fulfilling food group needs as defined in FBDG, or in the form of lower-cost food items that may contribute to a lower CoRD and more affordable healthy diet. In the case of CoRD, the ratio of the single market food environment definition to the original definition was referred to as a “convenience premium”, or, the additional amount that a household would need to spend to achieve the recommended diet when relying only on and single nearest traditional market.

Chapter 4 calculated a cost of recommended diet for food preferences (CoRD-FP) variable, which was a variation of CoRD. To estimate CoRD-FP, instead of using the only minimum priced food items in each food group as done with CoRD, food group costs were calculated from a weighted average of all food items available within a food group, where the weight of the individual items reflected local tastes and preferences. Expenditure shares—or the proportion of total household expenditure on a food group (e.g. fruits) that was attributed to an individual item (e.g. mangos)—were sourced from the most recent Sri Lanka’s 2016 Household Income and Expenditure Survey, and were treated as implied within-group food preferences[11]. The lowest price per edible serving observed for each item within a GN was multiplied by its associated expenditure share weight, and then each weighted average group cost was scaled to the recommended number of servings. This method followed closely that described by Mahrt et al (2019), used to assess diet costs in Myanmar[34].

Similar to the CoRD variable, the affordability was assessed by dividing CoRD-FP by household food expenditure, and the prevalence of unaffordability was assessed as the percentage of households with food expenditure less than CoRD-FP. Lastly, a ratio of CoRD-FP to CoRD was calculated and referred to as the “preference premium”. This represented the additional cost consumers would need to incur to meet FBDG while retaining their existing food preferences, rather than switching to only the lowest priced foods within each group, as CoRD assumes.

Aim 2: Assessing trends in the cost and availability of a healthy diet in rural Sri Lanka during Covid-19

Chapter 5 examined two of the same variables previously described—the FBDG-based dichotomous food availability variable and the CoRD variable—over the course of the full study period, from December 2020 to 2021. There were three objectives within Aim 2: 1) to describe changes in the R5N area in the availability and cost of a healthy diet and cost of individual food groups between December 2020 and ending December 2021; 2) to compare the changes in the cost of a healthy diet in the R5N area to a national average cost of a healthy diet; and 3) to compare changes in seasonal variation and trend of the cost of a healthy diet before Covid-19 and during Covid-19.

Analytical methods for the first objective consisted of calculating availability and CoRD variables for each month that follow-up data were available for. Due to Covid-19 restrictions, data collection activities were not possible during May 2021, June 2021, and August 2021, when the Delta wave was reaching its peak in Sri Lanka and national curfews as well as local containment policies were instated. Availability was estimated for all food groups (1 – all food groups were available in the variety required by FBDG, 0 – all food groups were not available) as well as for the individual food groups, using the variety requirements detailed in **Table 3.2.** CoRD was also estimated for the cost of total diet as well as the cost of individual food groups for each month of follow-up. Monthly estimates were then adjusted for inflation, using consumer price index (CPI) data from the International Monetary Fund (IMF)[35]. Adjusting for inflation better ensured that time trends were indicative of systematic changes in market conditions (supply and demand) for food as opposed to overall currency valuations. A non-food price index was used as opposed to total CPI in order to avoid removal of the temporal variation in prices that was relevant for studying food prices. A weighted average non-food price index was calculated, with expenditure category-specific price indices weighted by their relative size as a percent of total household non-food expenditure. Prices were stated in constant December 2020 (real) terms. Inflation adjusted CoRD monthly estimates were then displayed in an average plot.

Similar to the Aim 1 analysis, food availability and CoRD for each follow-up were also estimated using the restricted food environment definition, which limited each GN's access to one single traditional market as opposed to two. This provided a means of identifying months of follow-up when there were higher benefits in terms of food availability and cost savings from utilizing multiple market locations.

The second and third objectives of Aim 2 utilized secondary data that was accessed from Sri Lanka's national food price surveillance system, managed by HARTI. HARTI collects weekly retail price data from market locations across Sri Lanka's twenty-five districts (typically from one market location in each district). These weekly price data were converted to monthly means. To enhance comparability of the R5N and HARTI data sources, food lists were harmonized by restricting the analysis to only the common food items available in both sources. HARTI's food list for weekly price monitoring was shorter than that used for the R5N food environment study, consisting of just 69 unique food items, compared to the 175 unique food items surveyed in R5N. HARTI's food list also did not include any milk or dairy. Therefore, the CoRD in this analysis was referred to as CoRD-abbreviated.

For the second objective, HARTI data from December 2020 to December 2021 was used, but only for the months when there was also R5N data available. To test whether trends in the real abbreviated CoRD over this period were significantly different in the R5N area and HARTI national surveillance data, a generalized least squares model was fit, using a restricted maximum likelihood estimator to account for low sample size, as follows:

$$(\textit{CoRD-abbreviated})_{ijk} = (\beta_0 + b_{0i} + b_{0ij}) + \beta_1(\textit{Group})_{ij} + \beta_2(\textit{Time})_{ijk} + \beta_3(\textit{Group})_{ij}{*}(\textit{Time})_{ijk} + \varepsilon_{ijk}$$

$$b_{0i} \sim N(0,\tau^2),\ b_{0ij} \sim N(0,\gamma^2),\ \varepsilon_{ijk} \sim N(0, \sigma^2),$$

$$b_{0i},\ b_{0ij},\ \text{and } \varepsilon_{ijk} \text{ independent of each other}$$

The outcome of this model was the abbreviated CoRD for month *k*, in location *j*, nested within market index *i*. Random intercepts at the location level was used to account for clustering of standard errors within locations over time. The market index variable was created to account for further clustering of locations in the R5N area (i.e. GNs) due to sharing of traditional markets – random intercepts were thus used for market index values as well. Differences between groups (HARTI versus R5N) were allowed at baseline, using the *Group* variable. A linear term for calendar month (*Time*) was used, based on examination of locally weighted smoothed trends (*lowess*) that showed roughly linear trends, and an interaction term to test for a difference in slope between HARTI and R5N. The significance of this difference was assessed by the β_3 coefficient. Based on analysis of within-GN/market location correlation, an exchangeable residual correlation model was fit.

Assessment of seasonal variation and trend in the cost of a healthy diet, the third objective of Aim 2, was not possible using R5N data, due to missing months of data when data collection was not possible and due to the limited time period, during which typical seasonal patterns were likely disrupted by Covid-19. Instead, data for an extended time period—from December 2014 through December 2021—were accessed from HARTI. This enabled a national level analysis of whether or not there was a typical seasonal pattern in CoRD-abbreviated and how it may have changed during Covid-19.

Two different models were utilized to assess seasonal variation, which have both been used in prior studies of seasonality in food prices and cost of diets: a trigonometric model and a stochastic trend model[36,37]. Model fit statistics were compared between the two models and results were presented only for the stochastic trend model, which had a lower Akaike's Information Criteria test statistic. This model was adapted from *Gilbert et al* (2017) and *Schneider et al* (2021)[37,38].

$$\Delta_g(\textit{Log CoRD-abbreviated})_{lym} = (\textit{Log CoRD-abbreviated})_{lym} - (\textit{Log CoRD-abbreviated})_{lym-g-1}$$
$$= \beta_0 + \sum_{a=1}^{g-1} \beta_{m-a}(s_{m-a}) + \varepsilon_{lym}$$

The outcome variable in this model was the log of the first difference of the abbreviated CoRD for location *l,* year *y*, and month *m*, allowing for gaps between months of *g* (during which data were not collected or CoRD was infeasible). β_0 was therefore the estimated constant monthly increment, while β_{m-a} measured the monthly deviations from this trend, using monthly (seasonal) dummy variables s_{m-a}, defined as:

$$\text{Where } s_{m-a} = \begin{cases} 1 & a = m \\ -1 & g = 0 \\ -1 - \mathrm{g} & \mathrm{g} > 0 \\ 0 & otherwise \end{cases}$$

The first difference—or change in CoRD from one month to the next observed month—was used in order to achieve stationarity in the modeling, which better ensured accurate mean and variance estimates over the study period. Additionally, following *Schneider et al* (2021), the stochastic trend model was estimated first using only the data points where the abbreviated CoRD was feasible (i.e. where the variety requirements were satisfied for all FBDG except for dairy) and then, for comparison, again using data points where missing data was imputed using the maximum abbreviate CoRD observed for that month-year across all HARTI locations; this imputed method effectively treats an infeasible diet as the most expensive CoRD[37].

Seasonal variation was characterized in terms of the seasonal factors for each month, as well as the seasonal gap. Seasonal factors were attained by subtracting the grand mean log difference CoRD from the β_{m-a} coefficients, which was interpreted as percentage difference between the average CoRD for that month relative the average across all months (i.e. grand mean). The seasonal gap was then calculated as the difference between the maximum observed seasonal factor and the minimum seasonal factor. Models were fit separately to December 2014 – February 2020 and March 2020 – December 2021, to compare a typical seasonal pattern in CoRD to the pattern observed during Covid-19.

In addition to a comparison of the seasonal variation in CoRD prior to and during Covid-19, a comparison of the long-term trend in inflation-adjusted CoRD was attempted, again using a weighted non-food price index. A longitudinal model with a linear time trend and monthly dummies was fit to the data prior to Covid-19, accounting for within-location correlation with an auto-regressive correlation model, based on variogram evidence of rapidly decaying autocorrelation and comparison of model fit statistics. This model was then used to predict what a trend during March 2020 – December 2021 would have looked like based on the historical pattern, without Covid-19, which could then be compared to the actual data observed during Covid-19. However, cyclical variation in CoRD that was not anticipated by the model complicated this comparison. Other models introducing more flexible time parameters, such as a linear spline, were fit, but the variation in the trend between 2017 and 2020 was determined to be too unpredictable to allow for the extrapolation of a model-generated comparison for the February 2020 – December 2021 time period.

Aim 3: The influence of the food environment on diets in rural Sri Lanka: Testing associations between food availability, cost of a recommended diet, and dietary diversity among smallholder farmers

Multilevel Poisson regression was used to test associations between food environment exposures on dietary diversity. In this model, individual study participants (level 1) were nested within GNs (level 2) and GN random intercepts were used to account for the clustering of standard errors within GNs. Only one member from each household was included in the dietary survey, therefore there was no need to account for within-household clustering.

The primary outcome—a dietary diversity score (DDS)—was analyzed as a count variable. Both of the food environment exposures were analyzed as continuous variables, food availability measuring the total number of unique foods found in a GN and CoRD measuring the minimum cost of a healthy diet in LKR per person per day. In order to test associations between food environment exposures (level 2 variables) and dietary diversity while adjusting for individual and household (level 1) covariates, GN-mean covariates were calculated and included in the multi-level model. These represented the composition of study participants within a GN (e.g. proportion of female respondents, average household size, etc.). Their inclusion in the model helped to ensure that food environment-diet diversity associations were not confounded by differences in GN composition.

Several multilevel Poisson regressions were examined, building to the final model specification in the following order: 1) a random intercept only model; 2) a model adding GN-level variables, including food availability, CoRD, and district membership; 3) a model adding socio-demographic compositional variables; and 4) the final model, adding socio-economic, food security, and agriculture compositional variables. With each model, the random intercept variance was examined to see how much the added covariates reduced GN level variance in DDS. All regressions included only the study participants with complete information for all variables included in the model and GNs with 5 study participants or fewer were excluded. The multilevel equation for the final model, including compositional variables was as follows:

$$\begin{aligned}
\text{Log}(\text{DDS}_{ij}) = \ & \beta_0 + b_{0i} + \beta_1 \textit{Food availability}_i + \beta_2 \textit{CoRD}_i + \beta_3 \textit{District}_i + \beta_4 \overline{Age_{i.}} + \beta_5 \overline{Sex_{i.}} + \\
& \beta_6 \overline{Education_{i.}} + \mathrm{B}_7 \overline{Household\ size_{i.}} + \beta_8 \overline{Log(Expenditure_{i.})} + \\
& \beta_9 \overline{Socioeconomic\ status_{i.}} + \beta_{10} \overline{Food\ security_{i.}} + \\
& \beta_{11} \overline{Agricultural\ land\ holding\ size_{i.}} + \varepsilon_{ij} \\
& b_{0i} \sim N(0,\tau^2),\ \varepsilon_{ij} \sim N(0,\sigma^2),\ corr(b_{0i}, \varepsilon_{ij}) = 0
\end{aligned}$$

In this model, DDS_{ij} is the dietary diversity score of study participant j, $j = 1, \ldots, n_i$ from GN i, $i = 1, \ldots, 45$. β_0 represents the grand mean DDS and b_{0i} is the random intercept for GN_i . ε_{ij} represents the difference between the DDS for study participant i and the mean DDS for GN j. τ^2 is the GN random intercept variance in DDS and σ^2 is the within-GN variance in study participant DDS.

β_1 through β_3 assess the association between DDS and the GN-level (level 2) variables, β4 through β_7 assess the association between DDS and the socio-demographic composition variables, and β_8 through β_{11} assess the association between DDS and socio-economic, food security, and agriculture composition covariates. Poisson regression allows coefficients to be interpreted as semi-elasticities, therefore beta coefficients are the percentage change in DDS for a unit increase in the explanatory variable (as long as percentages are small).

Lastly, an additional Poisson regression model was run, adding GN-centered study participant (level 1) variables. These variables do not affect the validity of the associations between food environment exposures and dietary diversity, which are the key hypotheses being tested in this study, as group-centered level 1 covariates are independent of level 2 associations with the outcome. However, their inclusion in the model allowed further exploration of the relative importance of individual and household-level factors in explaining dietary diversity versus that of food environment exposures.

Ethical Considerations

Research protocols for the R5N impact evaluation and food environment sub-study were approved by the IFPRI IRB and Wayamba University of Sri Lanka’s Ethics Review Committee. Food environment research in traditional markets and village retail shops was not considered human subjects research, as this consisted of shop and stall audits to gather information about food prices and availability and other shop/stall characteristics that did not include personal information of vendors or shop owners. Nevertheless, it was frequently necessary to interact with vendors when prices were not displayed, which presented a time burden. Enumerators informed vendors of the purpose of the study, its duration, and asked if they would like to participate before the first data collection visit. Enumerators were also trained to manage their interactions with vendors in a way that would not interfere with the vendors business.

In the case of the household and dietary surveys, there were minimal risks to study participants and burdens were also mainly in the form of the time spent on the phone for interviews. Participants were informed that there would be a total of three interviews lasting approximately 30 minutes. To minimize time burden, enumerators were trained to conduct interviews in an efficient manner and to reschedule interviews at convenient times with participants when necessary. Participants were informed that they could withdraw at any point during the study. No direct benefits were provided to participants, but they were provided a total of 600 rupees reimbursement for their participation in the three calls.

Figure 3.1. Conceptual Framework

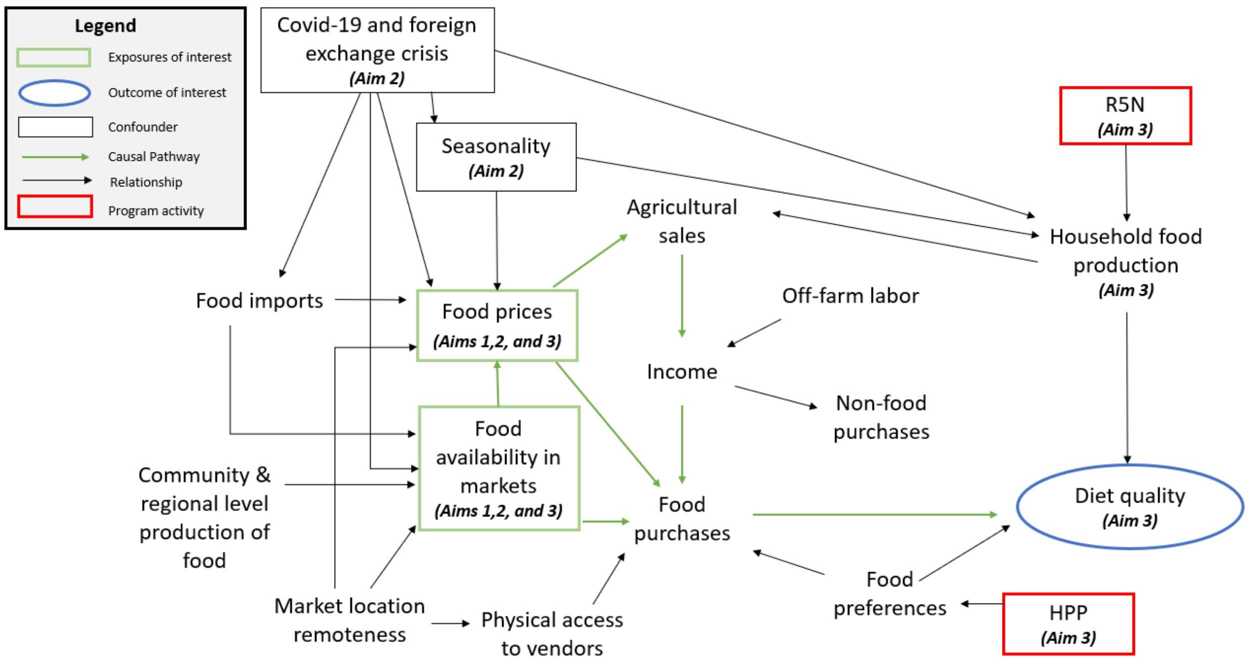


Figure 3.2. Map of the Sri Lanka R5N study area

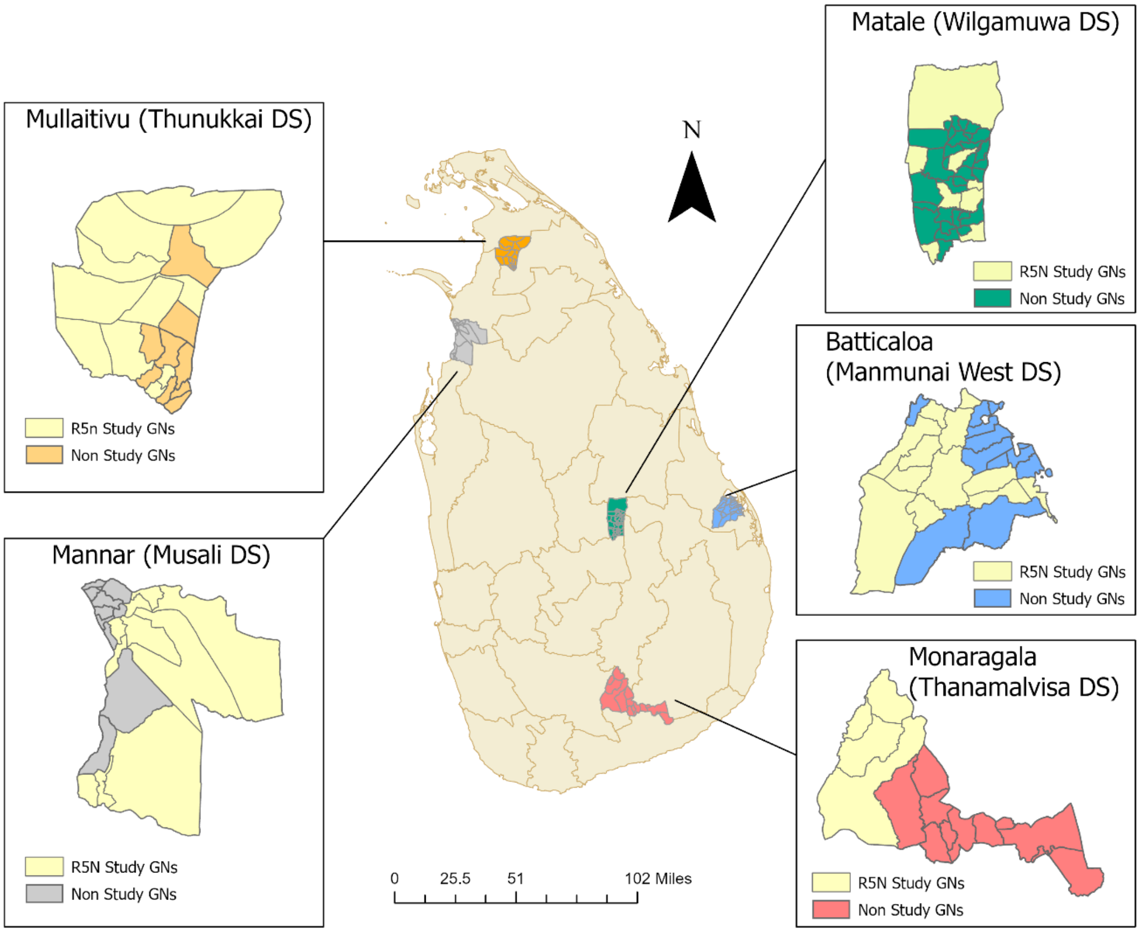


Table 3.1. R5N impact evaluation and food environment sub-study partners

Organization	Implementation vs. Research Partner	Role
World Food Programme	Implementation	Implementation of the R5N program
Foundation for Health Promotion	Implementation	Implementation of the health promotion intervention
International Food Policy Research Institute	Research	Lead study partner for the overall R5N impact evaluation
Medical Research Institute of Sri Lanka	Research	Data collection for household surveys
University of California – Davis	Research	Design and coordination of the dietary survey
Wayamba University of Sri Lanka	Research	Data collection for dietary surveys
Johns Hopkins University School of Public Health	Research	Lead study partner for the food environment sub-study
University of Peradeniya	Research	Data collection for the food environment sub-study

Table 3.2. Food Based Dietary Guidelines for Sri Lanka[17]

Food group	Recommended servings	Median servings	Variety requirement
Fruits	2 - 3 servings per day	2.5 servings	2 unique fruits
Vegetables	3 - 5 servings per day	4 servings	3 unique vegetables, including 1 green leafy vegetable
Fish, pulses, meat, eggs (protein-rich foods)	3 - 4 servings per day	3.5 servings	2 different protein sources required
Rice, bread, other cereals and yams (starchy staples)	6 - 11 servings per day	8.5 servings	2 unique starches
Milk and dairy	1 - 2 servings per day	1.5 servings	n/a
Nuts and oil	2 - 4 servings per day	3 servings	n/a

Source: Food-Based Dietary Guidelines for Sri Lankans, Ministry of Health, Nutrition Division (2011)

Table 3.3. NEMS-S Scoring System for Sri Lanka

Group 1: Unprocessed and minimally processed foods	
Food group	*Scoring*
Fruits	0 varieties = 0 points
	1 – 3 varieties = 3 points
	4 – 5 varieties = 5 points
	6 – 9 varieties = 7 points
	>= 10 varieties = 9 points
Non-starchy vegetables (excludes onions, cassava/manioc, and potato)	0 varieties = 0 points
	1 – 3 varieties = 3 points
	4 – 5 varieties = 5 points
	6 – 9 varieties = 7 points
	>= 10 varieties = 9 points
Chicken (frozen or fresh)	If available = 4 points
Eggs	If available = 4 points
Fresh or frozen fish and other seafood	If fresh or frozen fish is available = 4 points
	If other seafood is available = 2 points
Milk	If only full cream is available = 1 point
	If non-fat or reduced fat is available (even if full cream is also available) = 2 points
Yogurt	If only whole yogurt is available = 1 point
	If low fat is available (even if regular is also available) = 2 points
Whole grain and parboiled rice	If parboiled rice is available = 2 points
	If red or brown rice are available = 2 points
Other whole grains (barley, maize, millet, wheat)	If 1 variety is available = 1 point
	If 2 varieties are available = 2 points
	If 3 varieties are available = 3 points
	If >= 4 varieties are available = 4 points
Pulses (grams, dhal, soya beans, cowpea, chickpea)	If 1 variety is available = 1 point
	If 2 varieties are available = 2 points
	If 3 varieties are available = 3 points
	If >=4 varieties are available = 4 points
Whole grain or pulse flour	If whole wheat (*atta*) flour is available = 2 points
	If other whole grain flour is available, including finger millet (*kurakkan*) flour and red rice flour = 1 point
	If pulse flours are available, including lentil (*ulundu*) flour or gram flour (chickpea or other gram) = 1 point
Whole grain pasta or noodles	If whole-grain pasta or rice noodles are available = 3 points
Nuts and oil seeds (cashew, groundnut, pumpkin seeds, sesame seeds, coconut)	If 1 variety is available = 1 point
	If 2 varieties are available = 2 points
	If 3 varieties are available = 3 points
	If >=4 varieties are available = 4 points

Group 2: Processed or refined foods and culinary ingredients	
Food group	*Scoring*
Dried or canned fish	If available = 3 points
Oils	If available = 3 points
	If adulterated coconut oil is available = - 1 point
White rice (not parboiled)	If available = 1 point
White flour	If white flour (wheat or rice) is available = 1 point
Pasta and rice noodles	If only white pasta or rice noodles are available = 1 point
Whole grain bread	If whole grain bread is available = 3 points

Group 3: Ultra-processed foods	
Food group	*Scoring*
White bread	If available = - 1 point
Jam	If available = - 1 point
Instant noodles	If available = - 1 point
Biscuits	If 1 – 3 varieties available = - 1 point
	If 4 – 6 varieties available = -2 points
	If more than 6 varieties available = -3 points
Cakes	If available = - 1 point
Crisps and popcorn	If available = - 1 point
Snack mixes	If available = - 1 point
Sausages, meatballs, pre-prepared meat	If available = - 1 point
Processed soya meat	If available = -1 point
Ice cream	If available = - 1 point
Chocolate	If available = - 1 point
Candies	If available = - 1 point
Sugar sweetened beverages	If 1 – 3 varieties available = - 1 point
	If 4 – 6 varieties available = - 2 points
	If more than 6 varieties available = -3 points
Malted drinks	If available = - 1 point
Processed cheese	If available = - 1 point
Flavored, drinkable yogurt	If available = - 1 point

References

1. WFP and HARTI. *Sri Lanka Food Security Atlas: Livelihoods, Food Security, and Resilience*. (2015).

2. Department of Census and Statistics. *Poverty indicators - 2019*. http://www.statistics.gov.lk/Poverty/StaticalInformation/PovertyIndicators-2019 (2022).

3. World Health Organization. *Childhood malnutrition in Sri Lanka: A road map for the last mile*. (2020).

4. Dizon, F. & Herforth, A. *The Cost of Nutritious Food in South Asia. Policy Research Working Paper 8557*. http://www.worldbank.org/research. (2018).

5. Wfp. *Fill the Nutrient Gap Sri Lanka - Summary Report*. (2018).

6. World Food Programme. *Food Assistance for Assets (FFA) for Zero Hunger and Resilient Livelihoods: A Programme Guidance Manual*. (2016).

7. Olney, D. K. *et al.* Leveraging an Implementation– Research Partnership to Improve Effectiveness of Nutrition-Sensitive Programs at the World Food Programme. *Food Nutr. Bull.* 41, 18–37 (2019).

8. Jayatillake, P. J. & Mahalianaarachchi, R. P. Behavioral pattern of fruit & vegetable consumers in the 'Pola' (Fair) system in Monaragala district in Sri Lanka. *Jiangsu nong ye xue bao* 3, 33 (2007).

9. Liyanage, N. V. R. Behind the curtains of pola: Creating and negotiating local markets in Sri Lanka. (Ball State University, 2016).

10. Priyankara, E. A. C. *Present Status of Vegetable Direct Marketing in Selected Districts in Sri Lanka*. http://www.harti.gov.lk/images/download/reasearch_report/new1/191.pdf (2016).

11. Department of Census and Statistics. *Household Income and Expenditure Survey, 2016*. (2018).

12. Ahmed, S. *et al.* Suitability of Data-Collection Methods, Tools, and Metrics for Evaluating Market Food Environments in Low- and Middle-Income Countries. *Foods* 10, 2728 (2021).

13. Ballard, T. J., Kepple, A. W. & Cafiero, C. *The Food Insecurity Experience Scale: Development of a Global Standard for Monitoring Hunger Worldwide*. https://www.fao.org/3/as583e/as583e.pdf (2013).

14. Dizon, F., Herforth, A. & Wang, Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security* 21, 38–51 (2019).

15. Glanz, K., Sallis, J. F., Saelens, B. E. & Frank, L. D. Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. *Am. J. Prev. Med.* 32, 282–289 (2007).

16. Martins, P. A. *et al.* Validation of an adapted version of the nutrition environment measurement tool for stores (NEMS-S) in an urban area of Brazil. *J. Nutr. Educ. Behav.* 45, 785–792 (2013).

17. Nutrition Division - Ministry of Health. *Food Based Dietary Guidelines for Sri Lankans*. (2011).

18. Perera, W.D.A. *Tables of Food Composition for Use in Sri Lanka*. http://bfnvw.bfnsrilanka.org/foodcomp/ (1979).

19. Ministry of Agriculture Development, National Nutrition Program. *Food Composition Table for Nepal*. (2012).

20. Shaheen, N. *et al. Food Composition Table for Bangladesh*. (2013).

21. Wu Leung, W. T., Butrum, R. R., Chang, F. H., Rao, M. N. & Polacchi, W. *Food Composition Table for Use in East Asia*. (1972).

22. U.S. Department of Agriculture, Agricultural Research Service. *USDA National Nutrient Database for Standard Reference, Release 28*. http://www.ars.usda.gov/nea/bhnrc/mafcl (2016).

23. Golden, C. D. *et al.* Aquatic Food Composition Database. (2021) doi:10.7910/DVN/KI0NYM.

24. Herforth, A. *et al. Background paper for The State of Food Security and Nutrition in the World 2020*. (2020).

25. FAO, IFAD, UNICEF, WFP, and WFP. *The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets*. (2020).

26. Masters, W. A. *et al.* Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy. *Am. J. Agric. Econ.* 100, 1285–1301 (2018).

27. Headey, D. D. & Alderman, H. H. The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents. *J. Nutr.* (2019) doi:10.1093/jn/nxz158.

28. Longvah, T., Ananthan, R., Bhaskarachary, K. & Venkaiah, K. *Indian Food Composition Tables*. (2017).

29. FAO. *Minimum dietary diversity for women: An updated guide to measurement - from collection to action*. https://doi.org/10.4060/cb3434en (2021) doi:10.4060/cb3434en.

30. Arimond, M. *et al.* Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. *J. Nutr.* 140, 2059S–69S (2010).

31. The Voices of the Hungry Team. *Modeling Food Insecurity in Bivariate and Regression Analysis*. https://www.fao.org/3/bp091e/bp091e.pdf (2015).

32. Nguyen, P. H. *et al.* Unequal coverage of nutrition and health interventions for women and children in seven countries. *Bulletin of the World Health Organization* 100, 20–29 (2022).

33. Vyas, S. & Kumaranayake, L. Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning* 21, 459–468 (2006).

34. Mahrt, K., Mather, D. L., Herforth, A. & Headey, D. *Household dietary patterns and the cost of a nutritious diet in Myanmar*. http://dx.doi.org/10.2499/p15738coll2.133344 (2019) doi:10.2499/p15738coll2.133344.

35. International Monetary Fund. Consumer Price Index (CPI). *IMF Data* https://data.imf.org (2022).

36. Bai, Y., Naumova, E. N. & Masters, W. A. Seasonality of diet costs reveals food system performance in East Africa. *Science Advances* 6, (2020).

37. Schneider, K., Christiaensen, L., Webb, P. & Masters, W. A. *Assessing the Affordability of Nutrient-Adequate Diets*. https://openknowledge.worldbank.org/handle/10986/36485 (2021).

38. Gilbert, C. L., Christiaensen, L. & Kaminski, J. Food price seasonality in Africa: Measurement and extent. *Food Policy* 67, 119–132 (2017).

Chapter 4. Characterizing the food environment in 45 rural Grama Niladhari Divisions of Sri Lanka

Abstract

Food environment research is still growing in low and middle-income countries (LMICs), especially in rural communities, which are undergoing rapid food systems and nutrition transitions. More evidence to describe food environments would be useful not only to better understand their linkages with food access and diet quality, but also for policymakers and program implementers to better design and evaluate interventions that seek to improve nutrition. This study assesses food availability, costs and affordability in 45 Grama Niladhari Divisions (GNs) spread across five districts of Sri Lanka, where the World Food Programme (WFP) is implementing a food assistance-for-asset creation program. Surveys were carried out in traditional open-air markets and village retail shops in December 2020, collecting data on food availability and food prices of 175 unique food items. Several food environment indicators that have recently emerged were utilized in the study, including cost of diet indicators and a health score for retail shops. Few gaps in the availability of foods that make up a healthy diet were identified, and the cost of a healthy diet, estimated at 155.39 Sri Lankan Rupees (LKR) (or $2.63 2011 $PPP), was quite affordable, representing just 48% of food expenditure reported by households in the study area. However, ultra-processed foods were also widely available in retail shops, which may be a concern especially for households located far from markets. This evidence indicates that at baseline, food availability and affordability may not have been serious constraints to the effectiveness of WFP's program. However, future analysis will track changes in these indicators through 2021, when Sri Lanka was combatting simultaneous emergencies related to the COVID-19 pandemic and a foreign exchange shortage.

Introduction

Food environments have an important role in shaping consumers' food choices. Many studies in high-income countries have explored how differences in the quality of community food environments may explain inequities in access to food [1]. However, food environment research in low and middle-income countries (LMICs) is still at an early stage [2]. Improved monitoring and evidence-generation on food environments is crucial in LMICs, due to the rapid changes food environments and broader food systems are undergoing, and possible links between these changes and the double-burden of malnutrition.

Sri Lanka is experiencing simultaneous food system and nutrition transitions, with overweight and obesity on the rise, while undernutrition among vulnerable groups persists [3,4]. Evidence to characterize dietary intake is limited, but a previous assessment indicated that 73% of adults eat less than five servings of fruit and vegetables per day and 27% report “always or often” consuming processed foods that are high in salt[5].

Several types of constraints in local food environments relating to physical and economic access to food could contribute to such dietary problems. It is estimated that nationally, 54% of Sri Lankans cannot afford a healthy diet and this could be even higher in food insecure, rural areas[6]. Seasonal fluctuations in food prices and limited road and market infrastructure in some areas are also thought to limit access to nutritious food[7,8]. Still, studies examining these factors at the community-level, in traditional open-air markets and village retail shops frequented by local households, do not exist. Incorporation of these types of rural, remote communities and markets, which may only operate sporadically, have not been well covered within national food price data collection efforts, such as consumer price index (CPI) monitoring[9].

Descriptive evidence on food environments could be especially useful for organizations implementing programs that aim to improve diet quality by informing design aspects related to which interventions would be most appropriate and at what intensity they should be delivered. It can also provide contextual information for implementation research, shedding light on why or why not a program may have achieved its intended impact.

This study’s objective is to assess food availability and food costs—two key dimensions of the food environment—in drought and flood-prone rural areas of Sri Lanka where the World

Food Programme (WFP) is implementing a program (the “R5N” program) to enhance the resilience of smallholder farming households. The study makes use of several newly developed cost of diet indicators that have emerged from the food environment literature in order to measure diet costs in study communities. Data were gathered from traditional markets and village retail shops in December 2020.

This evidence will contribute to a broader impact evaluation of the R5N program, led by the International Food Policy Research Institute (IFPRI), and is timed to coincide with that study’s baseline survey. Among other outcomes, the R5N is being evaluated on whether it improves diets in participating households. Therefore, information on food environments, and particularly how they vary across different areas included in the study, may be useful in further understanding the context of household food access where R5N is implemented and how this could influence the magnitude of diet improvements.

Methods

Study design and setting

This study used a cross-sectional design, drawing on food environment and household data collected from 45 Grama Niladhari (GN) Divisions (Sri Lanka’s lowest administrative unit, each comprised of 3-7 communities) across five rural districts where the R5N program was implemented: Batticaloa, Mannar, Matale, Monaragala, and Mullaitivu. Data were collected through surveys with vendors of two different types of food outlets: 1) traditional markets; and 2) village retail shops. This analysis used baseline data collected in December 2020, with the aim of gauging the extent of any availability or affordability gaps that might influence the effectiveness of the R5N program prior to its implementation, as well as any systematic differences that may exist across the study area. Additional household data on expenditures were utilized from the baseline survey of that evaluation, also collected during December 2020–January 2021.

Study communities were located in the agro-ecological dry zone of Sri Lanka with high poverty, food insecurity, and malnutrition, which were criteria used by WFP in its targeting of the R5N program. Though districts included in the study were spread across the Nothern, Central, Eastern, and Uva provinces, study communities were all vulnerable to climate shocks (especially droughts and floods) and seasonal variation in food security. The R5N program is a type of asset creation intervention, in which participating households were provided with cash transfers in exchange for labor towards rehabilitation of community and household water infrastructure, as a means of increasing water availability, and subsequently, agricultural production, income, and diet quality.

In addition to limited rainfall, districts in the study area face other challenges that may affect local food environments. Roads, market infrastructure, and irrigation tanks sustained heavy damage in the Northern and Eastern Provinces during the conflict between the Government of Sri Lanka and the Tamil Liberation Tigers of Tamil Elam (LTTE) from 1983 to 2006, where the majority of the Tamil ethnic group resides [10]. Road and market infrastructure has also been historically underdeveloped in the district of Monaragala [8]. This may limit market access and exacerbate the impacts of climate shocks and seasonality on food availability and food prices. Post-harvest losses are also high, especially for fruits and vegetables, which may affect access to those foods in remote areas [7].

Sri Lanka’s food system was also affected by the coronavirus pandemic (COVID-19). The first cases were reported in March 2020 and curfews were put in place through May 2020. A second wave in October 2020 caused a brief lockdown in the capital of Colombo, but in December 2020, there were no restrictions on movement or market closures in the study area. Fear over the rising price of imports, which Sri Lanka relies on for essential foods such as wheat, lentils, dried fish, and milk, has also been a concern, as COVID-19 has exacerbated a foreign exchange crisis, causing the rupee (LKR) to lose value[8,11]. Price controls, a tools commonly used by the government, were put in place, including maximum allowable wholesale markups as well as maximum retail prices on items such as milk powder, lentils, and canned fish[12]. It is not clear how these policies in combination with the broader disruptions in global supply chains manifested themselves in the food environment of our study area. However, in December 2020, the situation was relatively stable compared to later in 2021, when the Delta variant emerged and an economic emergency was declared, in part due to rising food prices.

Though a variety of other retail outlet types exist—including streetside vendors and mobile vendors—this study implemented surveys only in traditional food markets and village retail shops. Traditional food markets, also known as 'pola' in Sinhalese or 'santhai' in Tamil, are open air markets that typically operate only once or twice a week, bringing together vendors of fresh and dry foods. These markets are preferred by rural consumers due to their perceived lower prices and freshness in comparison with other outlets [13]. In contrast, village retail shops focus on dry and processed foods and are more numerous throughout communities. Weekly grocery shopping is typically done in the traditional markets, which also serve as social and cultural centers in rural communities, though village retail shops may be used in cases of emergency, if a food runs out, or for spontaneous purchases [14].

Sampling and survey procedures

A purposive sampling approach was used to select markets and retail shops to include in the study. This relied on input from local stakeholders, including WFP field officers based in each of the five districts and village leaders in each of the GNs. For the market sample, the main markets used by households in each of the 45 study GNs were identified. There was no requirement for markets to be located within the GN's administrative boundaries. Study areas were contained within a relatively small portion of each district, so in most cases, markets included in the sample were utilized by multiple study GNs. Village leaders also indicated the names and locations of the three most frequented village retail shops within each study GN. In a few cases, less than three shops operated in GN, whereas in others, thirty or more shops were in operation. Three retail shops were sampled with consideration to budget and time constraints of enumerators, not based on representativeness.

The final sample included 16 traditional markets and 122 village retail shops. It should be noted that market formats in Mannar and Mullaitivu, the two northern districts, differed from traditional markets in the other three districts. Mullaitivu's markets were mainly permanent (i.e. open every day) as opposed to periodic markets, though with fewer vendors selling goods. No traditional markets were identified in the Mullaitivu study area, but there were two small towns just outside the study area where retail shops, located close together, sold a variety of foods. In the case of Mannar, these two clusters of shops were treated as individual markets.

For the purposes of this study, the households were linked to GN-level food environment which was defined as the two traditional markets closest to it and the retail shops sampled within its boundaries. The decision to include two markets in each GN's food environment was made based on the varying size of markets, their operation on different days of the week, and inputs from village leaders indicating that households may not use one market exclusively. To check the sensitivity of food availability and diet cost estimates to this definition of the food environment, separate estimates were also made for GN-level food environments comprised of only the single closest traditional market (and still including the village retail shops).

Separate questionnaires were developed for traditional markets and retail shops and programmed for mobile data collection using the SurveyCTO platform (Dobility, Inc., Cambridge, MA). Both questionnaires contained items to assess background characteristics and features of the market or shop (e.g. size, type of covering, access to refrigeration), followed by the availability and prices of a pre-defined food list. Food items included in the food list were identified using the Sri Lanka Household Income and Expenditure Survey 2016, which listed foods purchased by households, and the food list adopted by the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), the primary government agency responsible for collecting and analyzing agricultural market information [15].

The differences between the questionnaires were the following: the market questionnaire required enumerators to collect three different price observations for each food item, to account for the multiple vendors available, whereas only one observation was required for retail shops; and the retail shop questionnaire included an extended list of packaged a processed foods, to account for their relative focus on those product categories (though only availability was assessed for these items and not prices). A full list of the foods included in both questionnaires is included in **Appendix 1.4.**

Enumerators based in the study areas were recruited from the University of Peradeniya Faculty of Agriculture and underwent training in November 2020. Training topics included the study questionnaires, use of tablets and the SurveyCTO app, as well as recommended methods for collection of food prices, the latter of which was led by HARTI. Enumerators were instructed to gather the market price observations from different locations within the market and to visit markets at the time of day when the maximum number of vendors are present (usually mid-morning). A pilot testing was conducted in November, which also allowed enumerators to verify the retail shop and market locations. Data supervisors based at the University of Peradeniya provided feedback to enumerators based on the pilot testing results to improve accuracy and consistency across enumerators. Retail shops that could not be verified or had closed were replaced with new shops.

Food environment measures

A suite of food environment metrics were used to characterize food availability and food costs in the study area. Availability indicators included binary variables related to the presence, or required variety of foods to meet FBDG, as well as a version of the Nutrition Environment Measures Survey for Stores (NEMS-S) adapted for the study. Cost indicators included the cost of the recommended diet (CoRD), including two variations, the Cost of the Recommended Diet-Food Preferences (CoRD-FP) and a CoRD that was calculated from the single closest market rather than the two closest markets. Relative caloric prices (RCPs) were used to further examine the cost of specific food groups.

Availability measures

Food availability was assessed within each food group, both as a binary variable (0: no items available from the group; 1: at least one item available from the group) and as a continuous variable, the count of unique items that were available. Availability was assessed at the individual outlet level, in both retail shops and traditional markets, as well as the GN-level. Finally, the ability to source sufficient items to meet the variety criteria suggested by many food-based dietary guidelines (FBDG) (i.e. diverse items within a group) was assessed at the retail shop-, traditional market-, and retail and market (combined) GN-level. GN-level estimates were compared using the previously stated definition of a GN food environment, as including the *two* nearest traditional markets and the village retail shops in each GN, as well as a restricted definition, including only the single closest traditional market and the village retail shops. These within-group variety criteria and a summary of Sri Lanka's national FBDG are detailed in **Table 3.2**, in *Chapter 3*. GNs were considered to have gaps in their availability of sufficient foods to meet FBDG where these within-group variety criteria could not be met.

A version of the NEMS-S was also adapted for the study. The NEMS-S tool has been evaluated for validity and used extensively in the United States to measure food availability, food quality, and prices within retail stores[16]. Stores were awarded higher NEMS-S scores for greater availability of healthy food groups (e.g. number of fruit items) as well as for having healthier options of specific food types available (e.g. baked chips or fat-free hot dogs). NEM-S has also been adapted for use in LMIC contexts, such as an urban area of Brazil, where it was integrated with the degree of food processing, based on the NOVA classification system[17]. Under this scoring, foods were divided into three categories, with the first representing the least processed (including unprocessed) foods and the third representing ultra-processed foods[i]. Higher points were awarded for availability of foods in the first two categories and subtracted for availability of foods in the third category.

The NEMS-S scoring sheet utilized in this study is included in **Table 3.3.,** in *Chapter 3*. The model developed by Martins et al (2013) in Brazil was used as a starting point, due to the high level of specificity of the original NEMS-S tool to the United States context[17]. Further adaptations were made based on healthy and unhealthy food options in the Sri Lankan context, such as whole wheat and pulse flours, or dried fish. NEMS-S scores were estimated only for retail shops, in keeping with original purpose of the tool. Each study GN's NEM-S estimate was calculated as the mean score of the village retail shops sampled within its boundaries. Possible scores ranged from -21 (maximum availability of Group 3 foods with no other foods) to 69 (maximum availability of Group 1 and 2 foods with no Group 3 foods).

Cost and affordability measures

All food prices were first converted to standard units—LKR per grams or per milliliters—prior to estimation of cost of diet variables. For food items reported by vendors in non-standard units (e.g. bunches of leafy vegetables or pieces of fruit) a separate one-time data collection of weights was conducted to estimate the conversion factors. One enumerator from each district weighed the non-standard unit and the conversion factor used was the mean of all of the weights collected.

Each food item was then adjusted for non-edible portions. The Sri Lanka food composition tables were from 1979 and did not publish edible portion factors[18]. Therefore, edible portions were sourced from other food composition tables that did include edible portions,

[i] For the purposes of this study "ultra-processed foods" refer to those foods wherein processing has resulted in altered nutrient content, such that unhealthy ingredients (saturated and trans fats, sugar, and salt) are disproportionately high, and fiber and micronutrients are limited. While moderately processed foods can include healthy foods, such as canned vegetables and whole grain breads, ultra-processed foods refer to energy-dense, highly processed food categories, including salty snacks, sugar-sweetened beverages, and sweets

including: Nepal, Bangladesh, East Asia, and the United States [19–22]. The US food composition tables were the primary source, with Nepal, Bangladesh, and East Asia used to fill in gaps for regional foods less common outside of Asia. The Aquatic Food Composition Database was used for fish and seafood items [23]. When edible portion factors were not available for specific fish species, mean values were estimated at the genus, order, or class-level, depending on availability of estimates at these different taxonomic ranks.

The CoRD was estimated as the minimum cost of adhering to the Sri Lanka national FBDG. The methods used closely followed those developed as part of the Changing Access to Nutritious Diets in Africa and South Asia (CANDASA) project, described in Dizon, Herforth, and Wang (2019) and a background paper for the Food and Agriculture Organization (FAO) State of Food Security and Nutrition in the World (SOFI) 2020[24,25]. The Sri Lanka FBDG indicate recommended quantities of daily servings for six food groups, including: fruits; vegetables; rice, bread, other cereals and yams (starchy staples); fish, pulses, meat and eggs (protein-rich foods); milk and other dairy; and nuts and oil. These recommendations are included in **Table 3.2,** in *Chapter 3***.**

As a first step in estimating CoRD, food items from the market and retail shop surveys were grouped into one of the six FBDG food groups. Serving sizes for each food group were then converted into grams. This was done using example serving sizes provided in the FBDG, for example: one serving of fruit was equal to one orange or banana; 1 serving of starchy staples was equal to 50 grams of bread or 135 grams of cooked rice; and 1 serving of protein-rich foods was equal to 15 grams of dried fish or 1 egg. Prices per gram were then converted to prices per serving for each food item.

The minimum cost of achieving each food group recommendation was identified using the items with the lowest price per serving in each food group. However, additional requirements were utilized in food groups for which the FBDG encouraged variety. These included the following (also included in **Table 3.2,** introduced in *Chapter 3*): two unique fruits were required for the fruit recommendation; two unique non-leafy vegetables and one green leafy vegetable were required for vegetables; two unique starches were required for the starchy staple recommendation; and the protein recommendation required two different types of proteins (e.g., pulse and fish, or pulse and egg). These variety requirements were similar to those utilized in the FAO *SOFI* 2020 report and explained in its associated background paper[6,24]. Lowest cost food items were identified for the food environment defined for each of the 45 GNs, meaning that all of the food items available in the two nearest markets and the retail shops sampled in each GN were first pooled together, then sorted by cost.

The lowest cost items to meet each dietary guideline were then averaged together and multiplied by the number of servings recommended. Sri Lanka's FBDG articulate a range of servings for each food group and for this analysis, the median value of each range was used (e.g. 3 – 5 servings of vegetables were recommended, so the minimum cost of vegetables was set to 4 servings). As a final step, the six food group minimum costs were summed together to estimate the CoRD.

The affordability of a healthy diet was evaluated using CoRD metrics: 1) a percent of average household food expenditure, and 2) as the prevalence of households with food expenditure less than CoRD. Food expenditure data were attained from the baseline household survey implemented by IFPRI for the evaluation of the R5N program. Respondents were asked to report quantities of foods their household consumed in the previous week. These data were then converted to daily per capita figures according to household size (taken from the household roster). Quantities were multiplied by average food prices from the markets and retail shops to estimate expenditures. To make the food expenditure estimates more comparable to CoRD, non-milk beverages, sweets, condiments, and prepared foods were deducted, similar to methods used by Dizon, Herforth, and Wang (2019)[25]. Finally, CoRD was divided by the mean household food expenditure for each GN. A binary variable was also created at the household level to reflect whether household food expenditure was less than CoRD. This variable was used to estimate the prevalence of unaffordability in each GN.

Two additional variations of the CoRD metrics were also used in the study: the single market CoRD and the CoRD-FP. The single market CoRD restricts the GN-level definition of a food environment to one traditional market as opposed to two, as described above. This allows an assessment of the sensitivity of the CoRD calculation to the food environment definition used, but also the additional cost of the convenience for consumers of relying only on the traditional market that is closest to them. In addition to the difference in distance between markets, there are size differences that could affect the diversity of food items available, including low-priced food items, and differences in days of operation.

CoRD-FP is a variation of CoRD that instead of using the minimum-cost food items in each food group to estimate diet cost, it bases food group costs on a weighted average of all food items available within a food group, where the weight of individual items is thought to reflect local tastes and preferences. Expenditure shares—or the proportion of total household expenditure on a food group (e.g. fruits) that was attributed to an individual item (e.g. mangos)—were sourced from 2016 Sri Lanka Household Income and Expenditure Survey (HIES), and were treated as implying within-group food preferences. The lowest price per edible serving observed for each item within a GN was multiplied by its associated expenditure share weight, and then each weighted average group cost was scaled to the recommended number of servings. This method followed closely that described by Mahrt et al (2019) and used to assess diet costs in Myanmar[26].

As with the standard CoRD diet cost estimate, affordability was assessed for the single market CoRD and CoRD-FP as a percent of household food expenditure and as the prevalence of households with food expenditure that was less than the associated CoRD measure in the GN of residence.

In addition to CoRD, relative caloric prices (RCPs) were estimated to assess the cost of substituting starchy staples for different food groups, which may be a strategy for improving the micronutrient adequacy of diets in contexts like rural Sri Lanka, where undernutrition remains. Caloric costs may also be particularly relevant for explaining consumption patterns in food insecure contexts[27]. These methods followed those developed by Heady and Alderman (2019)[28].

To prepare the food price data, prices were first converted to LKR per kilocalorie. These data were again sourced from available food composition tables that typically articulate the energy content per 100 grams edible portion. In this case, it was possible to use the India food composition tables for many of the food items, which did not include edible portion coefficients, but did include energy content per 100 edible grams, and covered the majority of items in the study's food lists[29]. Food composition tables from the United States, Nepal, and Bangladesh were used to fill in gaps.

RCPs were estimated by calculating as the ratio of three lowest caloric price items of each target food group, relative to a weighted index of starchy staples costs. Starchy staples were weighted by their availability in the national food supply. The national supply for each starchy staple (in kilocalories/capita/day) was sourced the FAO Food Balance Sheets, using FAOSTAT, which indicated that rice formed 71% of availability, wheat represented 20% of availability, and the remaining 9% was comprised of cassava, potatoes, and maize[30]. Food items from the survey that were included in each of these starchy staple groups are identified in **Appendix 1.4.** Within each group, the median caloric price for each GN was identified, then the starchy staple index was calculated by multiplying each median value by its weight.

The numerator used in the RCP ratio was formed by taking the mean of the three lowest caloric price items in each food group. These values, in addition to the prices used in the starchy staple index, were again sorted at the GN level using the markets and retail shops that defined the food environment. RCPs were calculated for 14 food groups in order to compare relative costs between healthy and unhealthy items. Many packaged foods included in the unhealthy food group categories were not initially part of the food price data collection in December 2020; these were rather collected in July 2021, however, staple food prices used in the denominator of those RCPs are also gathered from July 2021 so there is no time discrepancy within those indicator values.

Results

Characteristics of the traditional markets and village retail shops included in the study are shown in **Table 4.1.** The number of traditional markets and village retail shops sampled across the districts varied in accordance with number of study clusters in each district. However, market availability was also lower in the Northern Province, where only two and three main markets could be identified in Mannar and Mullaitivu, respectively.

Almost half of the traditional markets sampled were medium-sized, with 16 to 50 vendors, though in Mannar, both traditional markets in the study had five vendors or less. This was due to the structural difference of markets in Mannar, where clusters of retail shops and green grocers located in towns, nearby traffic junctions assumed the role of a market. Matale and Mullaitivu both included large markets, with 51 vendors or more. Only 13% of traditional markets had access to refrigeration for storage of perishable foods, including animal-source foods, whereas 50% had access to water via a pump or tap, 56% had electricity, and 63% had a dedicated waste collection area. Although 63% of traditional markets were accessible via a paved road, only 20% of markets in Matale had access via paved roads, which could suggest more remote locations.

As compared to traditional markets, a larger percentage of village retail shops had electricity (98%) and refrigeration (85%). This could be a result of retail shops often being attached to family residences, which typically have electricity. Village retail shops were less accessible via paved roads, which may be explained by their less-central locations, often away from main roads. Village retail shops in Matale were again those least accessible via paved roads. The majority of retail shops were small (10 square meters or less of surface area), though Monaragala had larger-sized shops, 58% of which were 11-20 square meters and 25% were more than 20 square meters.

Food availability in the R5N area

Though gaps in food availability were found in individual traditional markets and retail shops, few limitations were identified at the combined GN-level, as shown in **Table 4.2.** Sourcing foods from the two nearest traditional markets—or even the single closest market—and the retail shops sampled within each GN would enable the majority of households to follow FBDG with respect to the variety criteria imposed in this study. Only in Batticaloa were there instances of insufficient variety: when allowing each GN to source from two markets, only 75% of GNs were able to supply two unique fruits and 83% were able to supply and milk or dairy products, among the food outlets sampled. When restricted to just the single nearest traditional market, only 42% of GNs in Batticaloa could supply sufficient fruits for FBDG, and although 83% could still supply milk and dairy, in this scenario availability gaps for vegetables appeared as well. However, with the exception of Batticaloa, using two traditional markets or just one made almost no difference in physical availability.

The availability results for traditional markets and village retail shops confirmed the product specialization that was expected based on the literature review, that retail shops would offer relatively few fresh fruits and vegetables, whereas the markets would offer a range of fresh and dry foods. Still, only 38% of markets in the study had milk or dairy products available for purchase and these were also only available in 56% of the retail shops. Market availability was most constrained in Batticaloa, where only starchy staples were available with sufficient variety (two unique items) in all four markets surveyed.

For consumers residing in the study area and faced with these food environments, effective strategies for sourcing sufficiently diverse foods may vary by food group and district. In Batticaloa and Mannar, fruits and vegetables were only available in traditional markets, and in Batticaloa, residents in over half of the GNs would need to travel to a slightly further away market to source sufficient fruits and vegetables. For milk and dairy products in Batticaloa, Mannar, and Matale, retail shops also play a role in filling supply gaps in the food environment, especially in Matale where milk and dairy were completely absent from the traditional markets surveyed.

Availability was also assessed for more specific food groups and the average count of food items within each food group was estimated; those more detailed results are available in **Appendix 2.1.** These results highlight the wider availability across the five districts of dried fish relative to fresh fish and the more limited availability of other flesh meats. Milk availability was also more limited relative to other dairy products, such as yogurt and curd. At the combined GN-level, Mullaitivu and Monaragala had the greatest depth of availability within most categories, measured by the count of unique varieties, whereas Mannar and Batticaloa frequently had the lowest depth of availability.

Ultra-processed foods were widely available in retail shops across the study area, especially sugar-sweetened beverages, salty snacks, instant noodles, processed soya, biscuits, candy, and chocolate, as shown in **Table 4.3**. Perishable categories of ultra-processed foods were less available. Though 85% of retail shops in the sample had refrigeration, shelf space within refrigerators is often limited and prioritized for beverages. Retail shops specialized in snack foods as well as other ultra-processed foods that may substitute for lesser processed foods in meals. These items—like instant noodles and processed soya—may appeal to consumers partly for their convenience, ease of preparation, and taste, factors that may be important in retail shop purchases, which tend to be less planned in comparison with market shopping[14].

The adapted NEMS-S tool was used in retail shops as a means of weighing the balance between availability of: unprocessed and minimally processed foods (Group 1), which are important components of a healthy diet and should be encouraged; processed or refined foods or culinary ingredients (Group 2), which may also form part of a healthy diet, though are less encouraged than items in Group 1; and ultra-processed foods (Group 3), which are to be limited. **Figure 4.1** displays the district average score for retail shops in each district for each of the three groups, as well as the NEMS-S score, which is the sum of the three group scores.

The mean scores for Groups 2 and 3 were similar across the five districts, indicating that there was not much variation in the total supply of processed and ultra-processed foods at district-level in the retail shops sampled. Difference in overall NEMS-S scores were rather driven by district variation in the availability of unprocessed and minimally processed foods. Retail shops in Monaragala had an average Group 1 score of 22.2, which was double that of the two lowest districts, Batticaloa and Mannar. This could be a result of the larger size of retail shops in Monaragala, which may enable vendors to offer a wider range of all types of food, including unprocessed and minimally processed foods.

Food costs and affordability in the R5N area

The mean cost of a healthy diet (CoRD) was estimated to be LKR 155.39 per person per day in the study area (equivalent to $2.63 in 2011 PPP$). This ranged from a low of LKR 145.28 in Mullaitivu to a high of LKR 179.95 in Monaragala. CoRD results by food group are presented in **Table 4.4** and as the total cost of adhering to Sri Lanka's FBDG in the first column of **Table 4.5.**

District-average costs of individual food groups were estimated at the traditional market-, retail shop-, and combined GN-levels. In the case of traditional markets and retail shops, FBDG costs were estimated for individual outlets, based on the lowest price items available in the market/shop, and the district means are shown in **Table 4.4.** These estimates include only those outlets that were able supply the variety requirements imposed in this study (e.g. 2 unique fruits, or 3 unique vegetables including one green leafy vegetable). For this reason, it should be noted that the fruit and vegetable recommendation costs from retail shops were drawn from a small number of shops, whereas districts with missing values indicate that no retail shops had the requisite variety of items. This reflects the lower availability of fresh fruits and vegetables that was described in **Table 4.2** and **Appendix 2.1**.

The lower cost estimates at the combined GN-level demonstrates the cost savings that can be achieved by sourcing lowest price food from multiple traditional markets and retail shops, especially for protein-rich foods, which costed LKR 17.72 for 3.5 servings on average at the GN-level, 38% lower than the market average, and 42% lower than the retail shop average.

The lowest cost food items that were selected in each GN are listed in **Appendix 2.2.** These appear to be realistic diets for the most part, however, rice was not selected as one of the two lowest cost starchy staples in several GNs, and in the context of Sri Lanka, it is likely that a household would consume rice on a daily basis.

The milk and dairy recommendation of 1-2 servings per day was the most expensive, accounting for 35% of CoRD using food environment-level minimum costs. It was also the most expensive on a per serving basis, costing LKR 34.48 per serving, followed by fruits, which cost LKR 8.02 per serving. The protein group recommendation was relatively low cost (LKR 17.72 in total and LKR 5.06 per serving) in comparison with other recommendations, due to the affordability of pulses and dried fish, which are lower-priced alternatives to more expensive protein foods such as meat, eggs, and fresh fish. Starchy staples, including grains, roots and tubers, bread and noodles, were the second most expensive group, due to the higher quantity of servings recommended in Sri Lanka's FBDG.

The district variation in food group costs was greatest for vegetables and milk and dairy, which had ranges of 28.44 LKR and 21.19 LKR, respectively (using combined GN-level costs). Monaragala had the highest vegetable cost due its green leafy vegetables, which were significantly higher-priced than other districts. The milk and dairy recommendation was most expensive in Mannar, due to the lack of milk availability in markets and retail shops surveyed there, which would require households to rely on higher priced alternative dairy products (e.g. yoghurt or curd).

Variation in food group costs were also assessed at the combined GN-level using coefficients of variation (CV). Fruits and vegetables were the most variable, with CVs of 37% and 33% respectively. Meanwhile starchy staples were the least variable at the GN level, with a CV of 16%.

As with the analysis of food availability, the cost of a healthy diet was also compared when GN-level estimates were restricted to the single nearest traditional market (still retaining the village retail shops sampled within each GN). The ratio of the single market CoRD to the standard CoRD measure was calculated, which could be thought of as a *convenience premium*, or the additional cost a household would need to incur when sourcing foods for a healthy diet only using the traditional market closest to them.

The CoRD-FP was also compared to standard CoRD to assess the additional cost of consuming a healthy diet that, rather than include only the minimum cost food items within each FBDG group, instead reflects consumers preferences within each group. These preferences are implied by expenditure shares sourced from Sri Lanka's 2016 National Household Income and Expenditure Survey, which were used to calculate a weighted average cost for each food group. The ratio of CoRD-FP to the standard CoRD was again calculated, this time to reflect a *preference premium*.

A comparison of CoRD, the single market CoRD, and CoRD-FP with their associated premiums is shown in **Table 4.5**, by district. **Appendix 2.3** contains additional results to compare across food groups. On average, the convenience premium was small, with the single market CoRD just 8% higher than the standard CoRD. However, in Batticaloa, the premium was highest, at 21%. Of the four traditional markets surveyed in this district, two were small in size, both including 15 or fewer vendors; therefore, within Batticaloa, there could exist differences in the availability of low-cost foods that affects CoRD, which is more apparent when restricting to a single market. Where available, common low-cost foods may also vary in price across markets within Batticaloa. Across food groups, protein-rich foods had the largest convenience premium (1.41), which is likely the result of common low-cost food items (e.g. sprats and red dhal) not being universally available, and the large cost increment of alternative items within the protein group.

In contrast, the preference premium based on CoRD-FP was large, on average 24% higher than CoRD. This was highest in Matale and Mullaitivu. Among the costs of individual food groups, the preference premium was again highest for protein-rich foods, 4.94. This reflects the price discrepancy between low-cost proteins that are selected by the standard (minimum cost) CoRD vs. protein-rich foods that Sri Lankans prefer, which may include more expensive items like fresh fish and chicken.

Affordability indicators are included in **Table 4.6**. Using expenditure data collected from 1,369 households that participated in the baseline survey of the R5N impact evaluation, daily per capita food expenditure was estimated (with district means displayed in the table). Affordability was assessed as the GN-level CoRD as a percent of GN-mean food expenditure, and as the prevalence of households that could not afford CoRD (i.e. households with per capita food expenditure less than CoRD). The same was repeated for CoRD single market and CoRD-FP.

Across the 45 GNs, CoRD was on average 48% of food expenditure. These food expenditure estimates indicate that on average, households are already spending 2.3 times as much as CoRD, indicating that a healthy diet in the study area is highly affordable. The prevalence of households with food expenditure lower than CoRD, is correspondingly low, on average 15%, but as high as 24% in Matale.

Affordability estimates using the single market CoRD calculation changed only marginally, with the exception of Batticaloa, which had the highest convenience premium. The affordability of a healthy diet is further underscored by the CoRD-FP results, which show that food expenditure in December 2020 was sufficient for 40% of households to consume a diet according to FBDG while maintaining within-food group preferences (i.e. without substituting lower-cost, lesser-preferred food items). Only in Matale and Mullaitvu was the prevalence of unaffordability significantly higher than 50%.

Food costs were also estimated relative to the price of a typical basket of starchy staples, using RCPs, as shown in **Figure 4.2**. In this figure, the primary axis displays the RCP ratio, calculated as the caloric price of the target food group divided by the caloric price of a basket of starchy staples, while the secondary axis provides a qualitative categorization of the cost, following the thresholds set by *Headey and Alderman* (2019)[28]. Non-milk dairy products and green leafy vegetables were the most expensive relative to starchy staples, followed by flesh meats. In contrast, pulses, nuts (including coconuts), oils, and sugar were all approximately the same caloric price as starchy staples. The RCPs provided more evidence of the high price of green leafy vegetables in Monaragala as compared to the other districts in the study area.

Vitamin-A rich fruits and vegetables, including ambarella, guava, mango, melon, papaya, passionfruit, carrot, pumpkin, and sweet potato, were more expensive relative to starchy staples than other fruits. Similarly, green leafy vegetables, which are sources of provitamin A carotenoids and iron, were on approximately 2.5 times as expensive as non-leafy vegetables on a caloric basis.

The RCPs also highlighted the varied costs of different types of protein-rich foods. Animal sources of protein, including meat, fish, and eggs, were all more expensive than pulses. However, within animal source proteins, significant cost savings are still possible through dried fish, which are relatively cheap, about half the caloric price of fresh fish and seafood on average. Milk was also relatively cheaper than meat, eggs, and fresh fish and seafood, and much cheaper than other dairy products.

The relative cost of ultra-processed foods varied by product category. Certain foods were very cheap, including instant noodles and biscuits, while sugar sweetened beverages (SSB) and sweets were still relatively expensive. With the exception of Monaragala, where ultra-processed foods were consistently cheaper than in the other districts, there was little variance across districts relative to the variance seen in the perishable, unprocessed food categories, such as fruits, vegetables, and meats.

Discussion

In December 2020, food environments in the R5N study area could be characterized as offering food that was sufficiently available and affordable for households to attain healthy diets. With few exceptions, GN-level food environments, comprised of local retail shops and the two nearest traditional markets, offered a diversity of food groups, with additional depth within groups where variety is encouraged, such as fruits and vegetables. The cost of a healthy diet was LKR 155.39 ($2.63 2011 PPP$) per person per day, represented 48% of average household food expenditure and just 15% of the households included in the R5N impact evaluation study appeared to have insufficient income to afford that diet. Even a more expensive diet (CoRD-FP) that meets FBDG and reflects consumer preferences was affordable to 40% of the households surveyed.

The preference premium associated with protein foods was large (4.95) relative to other food groups, reflecting the significant difference between the low-cost protein-rich items selected in the standard CoRD measure (typically dried sprats or another dried fish and red dhal) versus other preferred protein-rich foods, such as fresh fish, chicken, and eggs, which are all included in the CoRD-FP weighted average. This premium was larger than that estimated in Myanmar using similar methods, which found the cost of protein-rich foods under CoRD-FP to be 3.5 times higher than CoRD, however, protein foods also had the highest premium in that study[26].

These estimates of the affordability of a healthy diet in Sri Lanka were significantly more optimistic than previously available estimates. The R5N CoRD of $2.63 2011 PPP$ can be compared to *SOFI 2020* report, which provided a national CoRD estimate of $4.70 2011 PPP$ for Sri Lanka using price data from the World Bank International Comparison Program (ICP), and Dizon, Herforth and Wang, who estimated CoRD to be $2.80 2011 PPP$ using household survey data or $3.20 2011 PPP$ using CPI monitoring data from Sri Lanka's Department of Census and Statistics[6,25]. However, it may be difficult to make these comparisons across different datasets. ICP data and CPI data may also be less representative of the prices faced by rural consumers in remote areas relative to household survey data.

Additionally, there are differences in the FBDGs used to generate CoRD estimates: *SOFI 2020* based its CoRD calculation on a set of ten national FBDGs from different regions of the world, whereas Dizon, Herforth, and Wang utilized a regional FBDG, informed by guidelines from Bangladesh, India, and Sri Lanka. National FBDGs are tailored to context and recommended quantities of food groups may differ. For example, the Sri Lanka FBDG's recommended servings of starchy foods is relatively high, and many other countries recommend more than two servings of dairy per day, and particularly in the Latin American and Near East regions, vegetable source protein is not substitutable for animal source protein[31]. This study provides an estimate that is specific to Sri Lanka's FBDG.

The low prevalence of unaffordability is likely explained by higher-than-expected expenditure estimates. Compared to the National Household Income and Expenditure Survey, R5N study households reported purchasing 46% more starchy staples, 97% more protein, 164% more vegetables, 146% more fruits, 114% more dairy, and 63% more oils (as measured in grams per person per day)[15]. Several explanations are possible, including: 1) that December is a month when expenditures are typically high - for farming families in particular, food stocks have run out, so more food needs to be purchased; 2) hoarding (especially of staple foods) may be taking place due to COVID-19 supply chain uncertainties; and 3) that households overestimated their expenditures during the phone surveys. Comparing this study's CoRD estimate to the expenditure figures from the 2017 national survey, using mean values for the five districts and adjusting for inflation, would result instead in a CoRD that is on average 80% of food expenditure as opposed to 45%.

Residents in the study area can achieve cost savings by spreading their purchases across multiple markets and retail shops. For example, a resident of the Amaithipuram GN in Mullaitivu who shopped only at the nearest traditional market, Akkaryan Kulam, could purchase red dhal for LKR 5.33 per serving and fresh hurulla fish for LKR 22.63, the cheapest items from two unique protein sources. However, if that resident also utilized the second nearest market, Kilinochchi, they could access a slightly cheaper pulse (green dhal for LKR 4.10 per serving) and if they shopped at their local retail shops as well, they could find dried sardines for LKR 4.50, which would be a significant cost savings over the fresh hurulla fish. Similarly, a resident of the Hambegamuwa GN in Monaragala would be forced to purchase a relatively expensive fruit (papaya for LKR 12.90 per serving) if confined to retail shops, however, waiting for a market day would give them access to bananas or mangos, both of which are cheaper.

These types of shopping strategies are especially useful for dairy products, particularly in Batticaloa and Mannar, where milk was difficult to find. This could require households to travel further to access it, or else pay higher prices for more expensive dairy products, such as yoghurt or curd.

Cost savings can also be achieved by substituting pulses and dried fish for other animal sources of protein, such as flesh meat and eggs, which are more expensive relative to starchy staples. However, in the in the context of lingering undernutrition, meat, eggs, and milk may still be required by households with young children as well as to address micronutrient deficiencies among other vulnerable groups[32].

Ultra-processed foods were widely available in retail shops throughout the study area. In contrast, retail shops tend to stock few fresh fruits and vegetables. Given the easier access of retail shops, which are open more frequently and are located closer to households, this could be a concern, especially for communities that are located far from markets. A study in Sao Paolo, Brazil found that greater neighborhood availability of SSBs was associated with more regular consumption of SSBs, while fruit and vegetable consumption was lower in neighborhoods lacking wet markets and supermarkets[33]. However, another study from Sao Paolo found no relationship between the density of fast-food restaurants and prevalence of overweight[34]. Additionally, this study in Sri Lanka found that some ultra-processed foods were relatively cheap, including instant noodles, which are often consumed as a meal and could risk substituting more nutrient-dense dishes.

This study is subject to several limitations which may influence findings. First, the food environment in which households operate was defined to include only the two closest markets, however it could be the case that households travel further away from the study area to utilize other markets that offer different foods for different prices (for example, larger city markets). Similarly, only traditional markets and retail shops were surveyed, but other types of food vendors also operate in the study area, including streetside vendors and mobile vendors, which have taken on more importance during COVID-19. It was not feasible within the scope and resources limitations of the study to gather data from further away markets, or these other vendor types at baseline, therefore, informed assumptions were made during the design stage as to the most important markets and vendor types to include.

Lastly, the validity of the adapted NEMS-S tool used in this study has not been evaluated, and the findings from it may be sensitive to decisions regarding the specific point values assigned to different food groups, as well as the list of foods included. Additional healthy or unhealthy food items may be sold in the retail shops that were not included in the questionnaire, however it was not feasible given time constraints to conduct full store audits using an open-ended food list. Further efforts may seek to improve on this adapted NEMS-S tool and also test inter-rater reliability.

Conclusion

This study found that in the R5N study area, healthy diets were available and affordable at baseline in December 2020. However this does not mean that households consumed a diet that was consistent with FBDG. Where diets remain inadequate, the implications for programs are that barriers could relate to consumer preferences and nutrition knowledge, and less due to lack of purchasing power for the majority of households. Though purchasing power may not have been a concern in December 2020, Sri Lanka's food environment has gone through many changes over the previous year due to COVID-19 and the macroeconomic crisis, and most of these changes are likely to place further constraint food access and erode purchasing power.

Future analyses from this study will utilize follow-up surveys among the same sample of markets and retail shops to examine how these indicators of availability and affordability have changed throughout the year, and whether they are associated with diet quality among study households.

Figure 4.1. Average NEMS-S score in retail shops, by district

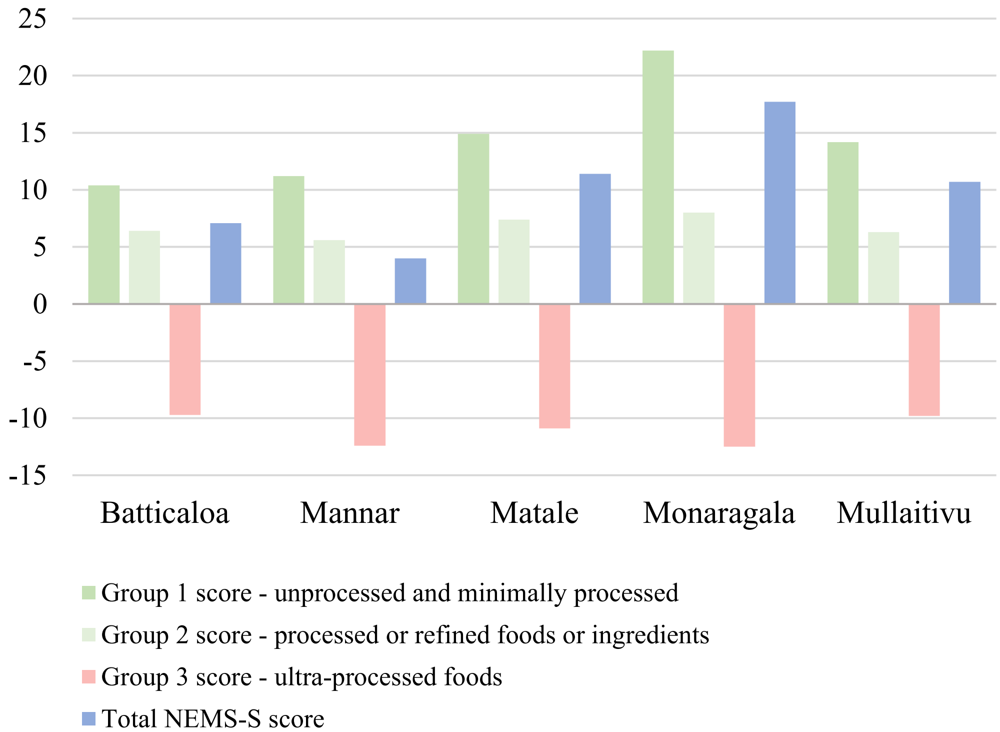


Figure 4.2. Relative caloric price of food groups, by district

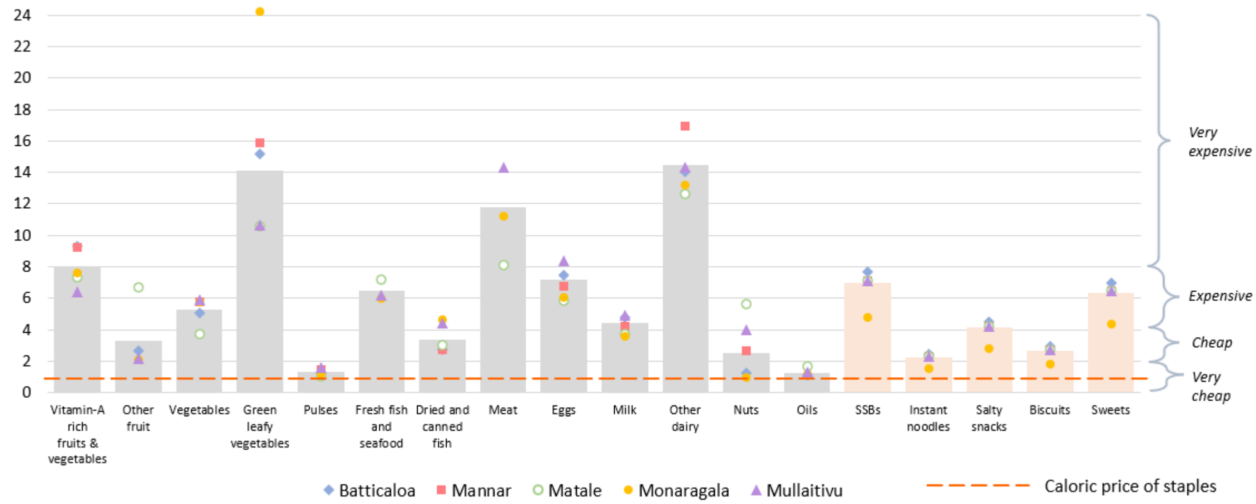


Table 4.1. Village retail shop and market sample characteristics, by district

	Batticaloa	Mannar	Matale	Monaragala	Mullaitivu	Total
Number of GN study clusters:	12	10	8	4	11	45
Province:	Eastern	Northern	Central	Uva	Northern	-
Traditional market characteristics	*n=4*	*n=2*	*n=5*	*n=2*	*n=3*	*n=16*
Number of vendors (%):						
5 vendors or less	25	100	-	-	-	19
6 - 15 vendors	25	-	-	50	67	25
16 - 50 vendors	50	-	80	50	-	44
51 vendors or more	-	-	20	-	33	13
Access via a paved road (%):	100	100	20	50	67	63
Permanent roof covering at least half of the market (%):	50	100	40	50	100	63
Access to electricity (%):	25	100	20	100	100	56
Access to refrigeration (%):	-	50	-	50	-	13
Access to water pump or tap (%):	-	50	60	50	100	50
Dedicated waste collection area (%):	-	100	80	50	100	63
Retail shop characteristics	*n=35*	*n=25*	*n=23*	*n=12*	*n=27*	*n=122*
Size (%):						
5 sq meters or less	17	28	26	-	71	31
6 - 10 sq meters	60	28	48	17	7	35
11 - 20 sq meters	17	36	22	58	22	27
21 sq meters or more	6	8	4	25	-	7
Access via a paved road (%):	69	41	19	58	58	50
Access to electricity (%):	97	100	100	100	97	98
Access to refrigeration (%):	80	100	83	100	74	85

Table 4.2. Availability of FBDG food groups at market-, retail shop-, and GN-level, by district, December 2020

	Fruits: 2 unique items	**Vegetables**: 3 unique items, including 1 leafy veg.	**Protein-rich foods**: 2 unique protein groups	**Starchy staples**: 2 unique items	**Milk and dairy**: 1 item	**Nuts and oils**: 1 item
Traditional markets						
Batticaloa (n=4)	50%	75%	75%	100%	25%	75%
Mannar (n=2)	50%	100%	100%	100%	50%	100%
Matale (n=5)	100%	100%	100%	100%	0%	100%
Monaragala (n=2)	100%	100%	100%	100%	100%	100%
Mullaitivu (n=3)	100%	100%	100%	100%	100%	100%
Total (n=16)	81%	94%	94%	100%	38%	94%
Village retail shops						
Batticaloa (n=35)	0%	3%	97%	94%	31%	86%
Mannar (n=25)	8%	0%	76%	96%	64%	92%
Matale (n=23)	0%	0%	100%	100%	83%	100%
Monaragala (n=12)	33%	0%	100%	100%	92%	100%
Mullaitivu (n=27)	7%	4%	78%	100%	41%	96%
Total (n=122)	7%	2%	89%	98%	56%	93%
Combined (GN-level) *2 traditional markets*						
Batticaloa (n=12)	75%	100%	100%	100%	83%	100%
Mannar (n=10)	100%	100%	100%	100%	100%	100%
Matale (n=8)	100%	100%	100%	100%	100%	100%
Monaragala (n=4)	100%	100%	100%	100%	100%	100%
Mullaitivu (n=11)	100%	100%	100%	100%	100%	100%
Total (n=45)	93%	100%	100%	100%	91%	100%
Combined (GN-level) *1 traditional market*						
Batticaloa (n=12)	42%	67%	100%	100%	83%	100%
Mannar (n=10)	100%	100%	100%	100%	80%	100%
Matale (n=8)	100%	100%	100%	100%	100%	100%
Monaragala (n=4)	100%	100%	100%	100%	100%	100%
Mullaitivu (n=11)	100%	100%	100%	100%	100%	100%
Total (n=45)	85%	91%	100%	100%	91%	100%

Legend	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%

*The percentage of traditional markets, village retail shops, or GNs supplying sufficient variety of each FBDG food group

Table 4.3. Availability of ultra-processed foods in retail shops, by district, December 2020

Retail Shops	Sugar - Sweetened Beverages	Salty snacks	Instant noodles	Processed meat	Processed cheese	Processed soya
Batticaloa (n=35)	91%	91%	94%	3%	3%	77%
Mannar (n=25)	96%	100%	72%	0%	0%	96%
Matale (n=23)	61%	96%	91%	26%	22%	100%
Monaragala (n=12)	67%	92%	100%	50%	8%	100%
Mullaitivu (n=27)	78%	85%	85%	0%	7%	85%
Total (n=122)	81%	93%	88%	11%	7%	89%

Retail Shops	Biscuits	Candy and Chocolate	Ice cream	Cakes	Malted drink	White bread
Batticaloa (n=35)	100%	97%	11%	54%	43%	3%
Mannar (n=25)	100%	100%	44%	80%	72%	0%
Matale (n=23)	100%	96%	35%	22%	9%	30%
Monaragala (n=12)	100%	100%	50%	75%	33%	42%
Mullaitivu (n=27)	100%	96%	4%	44%	48%	41%
Total (n=122)	100%	98%	25%	53%	43%	20%

Legend	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%

* The percentage of retail shops surveyed supplying at least one item in the food category

Table 4.4. Cost of Sri Lanka dietary guidelines by food group and district (in LKR[*]), December 2020

	Fruits: 2.5 servings	**Vegetables:** 4 servings	**Protein-rich foods:** 3.5 servings	**Starchy staples:** 8.5 servings	**Milk and dairy:** 1.5 servings	**Nuts and oils:** 3 servings
Traditional Markets						
Batticaloa	25.29	29.75	26.46	31.51	50.63	9.66
Mannar	24.43	30.59	55.67	48.51	78.00	6.52
Matale	25.72	19.91	20.00	27.57	-	6.64
Monaragala	15.17	47.37	26.16	33.59	63.70	6.45
Mullaitivu	17.25	26.94	30.11	31.18	42.31	7.08
Total – *mean (sd)*	21.97 (4.9)	28.37 (9.8)	28.74 (19.9)	32.60 (12.8)	54.71 (16.9)	7.44 (3.3)
Retail shops						
Batticaloa	-	27.48	34.04	58.31	64.88	8.89
Mannar	29.75	-	33.46	47.70	65.30	12.69
Matale	-	-	24.19	52.76	54.58	8.99
Monaragala	22.47	-	26.32	34.04	46.69	7.19
Mullaitivu	22.73	20.96	32.27	38.13	65.34	9.13
Total – *mean (sd)*	24.35 (4.5)	24.22 (4.6)	30.72 (14.0)	48.07 (26.1)	59.23 (14.6)	9.52 (7.1)
Combined (GN-level) *2 traditional markets*						
Batticaloa	23.88	26.16	12.05	29.53	58.55	4.31
Mannar	20.90	25.71	19.48	34.21	62.38	5.33
Matale	24.10	16.74	17.75	25.59	49.53	5.81
Monaragala	14.21	45.18	22.90	32.60	41.34	5.77
Mullaitivu	15.33	23.29	20.38	30.18	41.19	4.95
Total – *mean (sd)*	20.50 (4.2)	34.71 (11.7)	17.72 (5.1)	30.02 (4.4)	49.77 (13.3)	4.81 (1.1)

* LKR 59 is equivalent to $1 in 2011 purchasing power parity (PPP) terms

Table 4.5. Cost of a healthy diet, convenience, and preference premiums by district, December 2020

	(a) CoRD *LKR*[*]	(b) CoRD – 1 market *LKR*	*Convenience premium* (b)/(a)	(c) CoRD – FP *LKR*	*Preference premium* (c)/(a)
Batticaloa	152.41	186.83	1.21	306.84	2.01
Mannar	169.45	193.33	1.14	335.84	2.00
Matale	145.28	149.62	1.03	350.72	2.43
Monaragala	179.95	181.64	1.01	348.19	1.94
Mullaitivu	145.49	152.3	1.05	370.22	2.55
Total, mean (sd)	**155.39 (16.3)**	**168.37 (23.9)**	**1.08 (0.1)**	**344.88 (29.6)**	**2.24 (0.3)**

* LKR 59 is equivalent to $1 in 2011 purchasing power parity (PPP) terms

Table 4.6. Affordability of a healthy diet consistent with CoRD by district, December 2020

	Daily per capita food expenditure *LKR*	CoRD, as % of food expenditure	Prevalence of unafford - ability	CoRD – 1 market, as % of food expenditure	Prevalence of unafford - ability	CoRD -FP, as % of food expenditure	Prevalence of unafford- ability
Batticaloa	353.17	46%	15%	64%	30%	92%	52%
Mannar	392.86	42%	8%	47%	11%	84%	46%
Matale	251.05	57%	24%	59%	26%	143%	83%
Monaragala	318.74	57%	21%	58%	21%	110%	65%
Mullaitivu	404.86	36%	6%	38%	7%	91%	51%
Total	**345.02**	**48%**	**15%**	**51%**	**17%**	**105%**	**60%**

***** LKR 59 is equivalent to $1 in 2011 purchasing power parity (PPP) terms

References

1. Caspi, C. E., Sorensen, G., Subramanian, S. V. & Kawachi, I. The local food environment and diet: a systematic review. *Health Place* 18, 1172–1187 (2012).

2. Turner, C. *et al.* Concepts and methods for food environment research in low and middle income countries. *Agriculture, Nutrition and Health Academy Food Environments Working Group (ANH-FEWG)* 22–26 (2017).

3. NCD Risk Factor Collaboration. Rising rural body-mass index is the main driver of the global obesity epidemic in adults. *Nature* 569, 260–264 (2019).

4. Jayatissa, R. *et al. National Nutrition and Micronutrient Survey of Pregnant Women in Sri Lanka 2015*. (2017).

5. World Health Organization. *Non Communicable Disease Risk Factors: STEPS Fact Sheet Sri Lanka 2015*. https://www.who.int/ncds/surveillance/steps/STEPS-2015-Fact-Sheet-Sri-Lanka.pdf (2015).

6. FAO, IFAD, UNICEF, WFP, and WFP. *The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets*. (2020).

7. WFP and HARTI. *Sri Lanka Food Security Atlas: Livelihoods, Food Security, and Resilience*. (2015).

8. WFP. *Sri Lanka National Strategic Review of Food Security and Nutrition: Toward Zero Hunger*. (2017).

9. Gibson, J. & Rozelle, S. Prices and Unit Values in Poverty Measurement and Tax Reform Analysis. *World Bank Economic Review* 19, 69–97 (2005).

10. World Bank. *Socio-Economic Assessment of the Conflict Affected Northern and Eastern Provinces*. (2018).

11. Ondaatjie, A. Sri Lanka Is Running Out of Money for Imports as Delta Rages. *Bloomberg News* (2021).

12. Weerahewa, J., Hemachandra, D. & Roy, D. How agri-food chains in Sri Lanka fared during the stringent COVID-19 control measures? *IFPRI South Asia* https://southasia.ifpri.info/2020/05/13/how-agri-food-chains-in-sri-lanka-fared-during-the-stringent-covid-19-control-measures/ (2020).

13. Jayatillake, P. J. & Mahalianaarachchi, R. P. Behavioral pattern of fruit & vegetable consumers in the ‘Pola’ (Fair) system in Monaragala district in Sri Lanka. *Jiangsu nong ye xue bao* 3, 33 (2007).

14. Liyanage, N. V. R. Behind the curtains of pola: Creating and negotiating local markets in Sri Lanka. (Ball State University, 2016).

15. Department of Census and Statistics. *Household Income and Expenditure Survey, 2016*. (2018).

16. Glanz, K., Sallis, J. F., Saelens, B. E. & Frank, L. D. Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. *Am. J. Prev. Med.* 32, 282–289 (2007).

17. Martins, P. A. *et al.* Validation of an adapted version of the nutrition environment measurement tool for stores (NEMS-S) in an urban area of Brazil. *J. Nutr. Educ. Behav.* 45, 785–792 (2013).

18. Perera, W.D.A. *Tables of Food Composition for Use in Sri Lanka*. http://bfnvw.bfnsrilanka.org/foodcomp/ (1979).

19. Ministry of Agriculture Development, National Nutrition Program. *Food Composition Table for Nepal*. (2012).

20. Shaheen, N. *et al. Food Composition Table for Bangladesh*. (2013).

21. Wu Leung, W. T., Butrum, R. R., Chang, F. H., Rao, M. N. & Polacchi, W. *Food Composition Table for Use in East Asia*. (1972).

22. U.S. Department of Agriculture, Agricultural Research Service. *USDA National Nutrient Database for Standard Reference, Release 28*. http://www.ars.usda.gov/nea/bhnrc/mafcl (2016).

23. Golden, C. D. *et al.* Aquatic Food Composition Database. (2021) doi:10.7910/DVN/KI0NYM.

24. Herforth, A. *et al. Background paper for The State of Food Security and Nutrition in the World 2020*. (2020).

25. Dizon, F., Herforth, A. & Wang, Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security* 21, 38–51 (2019).

26. Mahrt, K., Mather, D. L., Herforth, A. & Headey, D. *Household dietary patterns and the cost of a nutritious diet in Myanmar*. http://dx.doi.org/10.2499/p15738coll2.133344 (2019) doi:10.2499/p15738coll2.133344.

27. Subramanian, S. & Deaton, A. The Demand for Food and Calories. *J. Polit. Econ.* 104, 133–162 (1996).

28. Headey, D. D. & Alderman, H. H. The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents. *J. Nutr.* (2019) doi:10.1093/jn/nxz158.

29. Longvah, T., Ananthan, R., Bhaskarachary, K. & Venkaiah, K. *Indian Food Composition Tables*. (2017).

30. FAO. Food supply. *Food Balance Sheets* (2022).

31. Herforth, A. *et al.* A global overview of food-based dietary guidelines. in *Annals of Nutrition and Metabolism* vol. 71 781–782 (2017).

32. Allen, L. Comparing the value of protein sources for maternal and child nutrition. *Food Nutr. Bull.* 34, 263–266 (2013).

33. Duran, A. C., de Almeida, S. L., Latorre, M. do R. D. O. & Jaime, P. C. The role of the local retail food environment in fruit, vegetable and sugar-sweetened beverage consumption in Brazil. *Public Health Nutr.* 19, 1093–1102 (2016).

34. Jaime, P. C., Duran, A. C., Sarti, F. M. & Lock, K. Investigating environmental determinants of diet, physical activity, and overweight among adults in Sao Paulo, Brazil. *J. Urban Health* 88, 567–581 (2011).

Chapter 5. Assessing trends in the cost and availability of a healthy diet in rural Sri Lanka during Covid-19

Abstract

Sri Lanka's food system has been profoundly impacted by the coronavirus disease 2019 (Covid-19) pandemic and a national economic crisis brought on by foreign exchange shortages and high sovereign debt obligations. Food price inflation increased rapidly in the second half of 2021 and news media reported long queues in urban areas to purchase essential food items. This study has sought to explore how food environments have fared in rural areas where the World Food Programme (WFP) is implementing a food assistance-for-assets program among smallholder farmers during December 2020 though December 2021. Survey data was collected at ten time points during this period in traditional open-air markets and village retail shops across 45 Grama Niladhari Divisions (GNs) to characterize the availability and cost of foods to make up a healthy diet. Though around 90% of the GNs supplied sufficient foods for food based dietary guidelines (FBDG) though the first half of the year, by September, only 62% had the required variety available. The cost of the recommended diet (CoRD) increased by 25% on average across the GNs, after adjusting for non-food price inflation from December 2020 to December 2021. Secondary data from Sri Lanka's national food price surveillance system also accessed and analyzed to produce comparable CoRD estimates, which established that: the increases in diet costs may have been more severe in rural areas like the R5N area, and that nationally, the monthly volatility of CoRD may have also increased during Covid-19 relative to a typical year. Strains placed on rural food environments threaten to limit access to a healthy diet particularly among vulnerable households, justifying WFP's programmatic approach that focuses on resilience and nutrition-sensitive activities. Future research-implementation partnership efforts may seek to incorporate information from food environment monitoring in program implementation in more real-time.

Introduction

Higher food prices, especially for nutrient-dense foods, have been shown to influence the consumption of nutritious food as well as nutritional status[1–3]. Low-income consumers who spend a greater share of their income on food may be particularly vulnerable to price increases[4,5]. New metrics have emerged to assess the cost of nutritious diets, which identify the lowest-cost foods that could satisfy nutrient requirements, minimum dietary diversity, as well as food-based dietary guidelines[6–8]. This evidence has improved understanding and motivated greater monitoring of food affordability, but there are still relatively few studies that have tracked changes in diet costs over time, including how they respond to shocks such as the Covid-19 pandemic or seasonality.

Covid-19 has disrupted food systems over the past two years, raising input costs, causing delays through food supply chains, and forcing closure of businesses and markets[9]. Effects on food prices were initially mixed, though international food prices rose in 2021 and inflation has continued since, driven by a complex set of factors, including a tightening in the global supply of staple commodities, especially wheat, and high input costs[10–12]. Perhaps the clearest economic impact of Covid-19, however, has been the loss of employment and income, which combined with increased consumer prices, could have devastating impacts on food access for poor households in particular.

Sri Lanka is a lower-middle income country (LMIC) that has experienced dramatic economic consequences from Covid-19. The emergence of the Delta variant in May 2021 brought on a prolonged period of lockdowns and other restrictions on mobility, and the loss of tourism revenues since the onset of the pandemic cut off a critical source of foreign exchange. This foreign exchange crisis forced the government to make difficult decisions regarding whether to use its dwindling reserves to service outstanding debt or pay for essential imports, including food[13]. The issue was exacerbated by inflation and a devaluating Sri Lankan Rupee (LKR), which caused the prices of key food imports, including milk powder and sugar, to increase. Declaring an economic emergency in August 2021, the government initially used price controls to keep prices low, but wide reports of food shortages and black market trading caused them to be lifted in October[14,15].

Domestic food production may have also suffered from a ban on chemical fertilizers, announced in April 2021. This ban, along with import bans on a host of non-essential goods, would have stemmed outflows of foreign currency and was promoted as a step towards more sustainable agriculture. However, in a phone survey, farmers reported high dependence on such fertilizers and not being prepared for this shift to organic[16]. Though the ban was lifted after just seven months, it was blamed for low yields following the May-August rainy season, which reportedly contributed to shortages and increasing prices for rice and vegetable[17].

The extent to which the cost of diet would follow the same temporal trend as food price inflation is not clear. A commonly cited source of bias in consumer price indexes is their use of fixed quantities of goods, which may not capture consumers' substitution to less expensive goods as relative prices change[18]. Where cheaper options of nutritious foods remain during this type of economic shock, consumers may still be able achieve low-cost, nutritious diets through substitution. Maintenance of low-cost diets in the presence of disruptions could stabilize food security, an important goal of food systems resilience[19]. However, one of the only studies to assess seasonality in the cost of a nutritionally adequate diet found that in Ethiopia, Malawi, and Tanzania, even after substitution, seasonal shifts were significant[20].

This study examines the cost and availability of nutritious foods during Covid-19 in remote, rural areas of Sri Lanka where the World Food Programme (WFP) is implementing a food assistance for assets intervention (the R5N program) to rehabilitate irrigation systems and improve resilience among smallholders. Sri Lanka is highly vulnerable to climate shocks, especially droughts, floods, and heat stress, which adversely impact agriculture[21,22]. Remote rural areas have also been understudied in the cost of diet literature, due to their exclusion from national price surveillance systems[23]. There is reason to believe that these areas could suffer more during shocks like Covid-19, as lack of market integration and trade are typically associated with greater price volatility and vulnerability to shortages[24,25]. Alternatively, as suggested above, the availability of locally produced foods in rural areas could provide a buffer against more expensive externally sourced foods.

Monitoring the cost and availability of nutritious food may provide useful contextual information for evaluating impacts from programs like the R5N program. Deterioration of purchasing power of beneficiaries could limit desired improvements in diet quality from the program. An impact evaluation of the R5N program is currently being carried out by the International Food Policy Research Institute (IFPRI), which this study of the local food environment is nested within and aims to inform.

The three primary objectives of this study are: 1) to describe changes in the R5N area in the availability and cost of a healthy diet and individual food groups between December 2020 and ending December 2021; 2) to compare the changes in the cost of a healthy diet in the R5N area to a national average cost of a healthy diet; and 3) to compare changes in seasonal variation and trend of the cost of a healthy diet before Covid-19 and during Covid-19.

The first objective uses primary data collected from ten rounds of market and retail shop surveys conducted in communities participating in the R5N study. The second and third objectives incorporate additional secondary data from a national food price surveillance system managed by the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI). Due to the limited study period and missing data during months of Covid-19 restrictions in the R5N area, the third objective relies solely on this secondary data. Food price surveillance data from HARTI are gathered from all 25 districts of Sri Lanka, but is typically from district capitals, cities, or larger towns, whereas R5N food environment data is more representative of remote, rural areas.

By addressing these objectives together, the study intends to enhance the implementation research of IFPRI and WFP, through the contribution of longitudinal food environment evidence, while also placing this evidence in a broader national context and in the context of historical patterns in the cost of a healthy diet in Sri Lanka prior to Covid-19.

Methods

Study design and setting

This study used a longitudinal design, gathering food availability and price data from 45 Grama Niladhari Divisions (GNs) (Sri Lanka's lowest administrative unit) beginning in December 2020 and ending in December 2021. GNs were spread across five districts of Sri Lanka, which included Batticaloa, Mannar, Matale, Monaragala, and Mullaitivu, and were concentrated in areas of each district where the R5N program is being implemented by WFP. R5N is targeted to agroecological dry zones with high levels of poverty, food insecurity, and malnutrition. The R5N areas struggle specifically with access to water for agricultural use, due to community reservoirs and other irrigation schemes that are inadequate and in states of disrepair. WFP's goal for the R5N program is to improve resilience and diet quality among smallholder farming families through a combination of rehabilitating irrigation systems, cash transfers during the period of rehabilitation work, agri-business training, and health education messaging.

During a typical year, food prices in Sri Lanka follow a seasonal trend shaped by a bimodal rainfall pattern. After the *maha* season (the primary rainy season), harvests of paddy rice, legumes, and vegetables push prices to yearly lows during March through May. Prices fall again following the secondary *yala* rainy season, around September. Between these periods, prices are higher, reaching peaks during November-December[26]. However, changes in these yearly patterns can result from climate shocks and variability, including droughts, flooding, and delays in monsoon onsets. Areas included in this study have a heightened vulnerability to shocks due to the few coping mechanisms low-income households have to rely on when food prices increase. They are also more reliant on markets for food when their own food production has been negatively affected.

During the study period, Sri Lanka experienced various food system-related shocks brought on by the Covid-19 pandemic, which also exacerbated pre-existing macroeconomic pressures. Sri Lanka's largest increase in Covid-19 cases took place from May to August 2021, as a result of the Delta variant. This period also saw a rapid acceleration in food price inflation, measured as the consumer price index (CPI) for food. These trends, along with specific Covid-19 related events and responses taken by the government to contain the virus while protecting its economic stability, are detailed in **Figure 2.2,** in *Chapter 2***.** Import bans on non-essential items, including certain foods, have primarily been used to stem the outflow of foreign currency, which Sri Lanka needs to service its debt. However, such policies could have a negative affect on food access, especially in the presence of inflation and if domestic food production is insufficient.

The study area was affected by market closures and curfews that took place as a result of the rise in Covid-19 cases during the summer of 2021, which also prevented data collection during May, June, and August. Excluding these months, a total of nine time points were included in the study.

There are key differences in the data collection points utilized in HARTI's national food price surveillance, which is relied on for the second and third objectives of this study. Markets surveyed by HARTI are typically from district capitals and are larger in terms of the number of individual food vendors that arrive at the market to sell. They offer a broader range of products to a larger consumer base in comparison to markets in the R5N area, which are disproportionately located in smaller-sized towns that service networks of remote villages and may not attract as large a number of vendors and consumers. Markets in the R5N may also operate less frequently, most times just once a week.

Data sources and survey procedures

Data were gathered from two types of retail outlets in the study area: traditional, open-air markets (also known as *pola* markets) and village retail shops. A purposive sampling procedure was used to identify the main traditional markets utilized by households in each of the 45 GNs, as well as the three most commonly utilized village retail shops in each GN for inclusion in the study. A total of 16 traditional markets and 122 village retail shops were sampled. In several GNs, there were less than three village retail shops in operation, so only one or two shops were included in the sample. Trained enumerators, recruited from the University of Peradeniya Faculty of Agriculture, visited markets and retail shops once per each month of follow-up, typically at the end of the month. Separate traditional market and retail shop questionnaires were designed and pilot-tested, using a pre-specified food list based primarily on the 2016 National Household Income and Expenditure Survey[27]. These sampling procedures have been described in more detail in *Chapter 3* (Methods).

This study defined GN-level food environments to include: 1) the village retail shops sampled within a GN's boundaries (between 1 – 3 shops); and 2) the 2 traditional markets that were geographically closest to the GN. Availability and cost estimates were then derived from the pooled data from all outlets associated with each GN. This was also an attempt to replicate in the study design rural consumers' tendency to shop around multiple retail outlets, which was described in literature and during field visits[28,29].

To examine sensitivity of availability and cost measures to the inclusion of multiple traditional markets, which assumes consumers would shop around, the study also compared results using an alternate definition of a GN-level food environment, which only included the single, geographically closest traditional market, and the 1-3 retail shops sampled within the GN boundaries.

Not all markets and retail shops could be surveyed for each follow-up period. For example, both of the traditional markets sampled in the district of Monaragala were closed from September to November 2021 due to a localized Covid-19 outbreak. Therefore, availability and cost estimates for the four study GNs in Monaragala during those months are derived solely from village retail shops. Similarly, retail shops across the study area were occasionally closed on the days when enumerators attempted to visit them. In these cases, the retail shops were not replaced with another outlet and the results are based only on the remaining retail shops and markets that could be reached during that month.

Primary data collected as part of this study were complemented with secondary data from HARTI. HARTI is based within the Ministry of Agriculture and conducts surveillance of farmgate, wholesale, and retail food prices in the 25 districts of Sri Lanka in order to monitor the terms of trade received by farmers, in addition to food access for consumers. Weekly retail data from HARTI were accessed from January 2014 through December 2021. Monthly averages were estimated for each food item monitored. For the second objective of this study (i.e., the comparison of R5N to the national average), HARTI data from December 2020 through December 2021 was compared to R5N data during the same period. For the third objective of this study, HARTI data from January 2014 – February 2020 was compared to HARTI data from March 2020 – December 2021, as a means of comparing pre-Covid-19 to during-COVID-19 diet cost measures.

To enhance comparability of the R5N and HARTI data sources in objective two, food lists were harmonized by restricting the analysis to only the common food items available in both sources. HARTI's food list for weekly price monitoring was shorter than that used for the R5N food environment study, consisting of just 69 unique food items, compared to the 175 unique food items surveyed in R5N. HARTI's food list did not include any milk or dairy (see **Table 5.1** below and Annex 1 with a full list of food items). Duplicate items (e.g., different varieties of rice) were excluded from both lists by taking only the lowest price item. A remaining difference in the data sources is that food prices in R5N were sourced from both traditional markets and village retail shops, while HARTI data were only from traditional, open-air markets and did not include retail shops.

Availability and cost measures

Food availability was assessed in the R5N study GNs for individual food items at each follow-up period. This was reported as the total number of GNs (out of a total 45) where the food item was available. Additionally, the feasibility of sourcing sufficient variety of items within food groups included in Sri Lanka’s national food based dietary guidelines (FBDG) was assessed. This was reported as the number of GNs where meeting the FBDG was feasible (e.g. the number of GNS where two non-leafy vegetables and one leafy vegetable could be found in the markets or retail shops sampled). Variety requirements were adapted from the Food and Agriculture Organization (FAO) *State of Food Security and Nutrition in the World (SOFI) 2020*[7] and a previous study on the cost of diet in the South Asia region specifically[23]. These variety requirements, along with serving recommendations for the six food groups included in the FBDG are shown in **Table 3.2**, in *Chapter 3*.

The cost of a healthy diet was measured using the Cost of the Recommended Diet (CoRD) indicator, adapted from the FAO *SOFI* report and Dizon and Herforth (2019), who utilized methods devised as part of the Tufts University-led Changing Access to Nutritious Diets in Africa and South Asia (CANDASA) initiative[7,23]. CoRD measures the minimum cost of following FBDG, by selecting the lowest cost items within each food group, ensuring the variety requirements detailed in **Table 3.2**, and taking the median number of recommended servings (e.g. 4 servings per day of vegetables). More detailed methods for estimating CoRD were described in *Chapter 3*.

As mentioned above, for the first objective, separate availability and CoRD estimates were also provided for the restricted, single market food environment definition, which only includes one traditional market for each GN.

This study also reported results for variations of CoRD using different food lists for the separate research objectives. To describe changes in the R5N study area from December 2020 to December 2021, estimates are based on the full food list specified in the R5N study (n = 175 items). In addition to the total diet CoRD, the cost of individual food group dietary recommendations were tracked across the study period. For the second and third objectives—comparison of R5N to the HARTI national average and comparison of HARTI pre Covid-19 and during Covid-19—an abbreviated CoRD utilized, restricted to only the items included in both the R5N and HARTI food lists. This abbreviated CoRD did not include the dairy food group.

CoRD estimates for the first and second objectives were adjusted for non-food price inflation, using CPI data from the International Monetary Fund (IMF)[30]. Adjusting for inflation better ensures that time trends are representative of systematic changes in market conditions (supply and demand) for food as opposed to overall currency valuations. A non-food price index was used as opposed to total CPI in order to avoid removal of the temporal variation in prices that is relevant for studying food prices. A weighted average non-food price index was calculated, with expenditure category-specific price indices weighted by their relative size as a percent of total household non-food expenditure. Prices were stated in constant December 2020 (real) terms.

For the analysis of seasonal variation in the third objective, nominal abbreviated CoRD was used as the outcome variable with a logarithmic transformation. This transformation allowed monthly differences to be interpreted in percentage terms, while keeping the scale constant across multiple years (which would not be possible using inflation adjustment) and still avoiding removal of the food price variation of interest, as described above.

Regression analysis

For the second objective, to test whether trends in the real abbreviated CoRD were significantly different in the R5N area and HARTI national surveillance data, a generalized least squares model was fit, using a restricted maximum likelihood estimator to account for low sample size. This included a linear term for calendar month (i.e. time), based on examination of locally weighted smoothed trends (*lowess*) that showed roughly linear trends, and an interaction term R5N versus HARTI to test for differences in slope. The model allowed for differences between the R5N and HARTI estimates at baseline. Based on analysis of within-GN/market location correlation, an exchangeable residual correlation model with GN/market location-specific random intercepts was fit, which were nested within a market-group index variable that accounted for the clustering of GNs in the R5N area that shared the same markets.

For the third objective, restricted to HARTI data, two different models were utilized to assess seasonal variation, which have both been used in prior studies of seasonality in food prices and cost of diets: a trigonometric model and a stochastic trend model. Stochastic trend model are less efficient due to the inclusion of 11 monthly dummy parameters in comparison with the more parsimonious trigonometric models, and have also been shown to overestimate the extent of seasonality in food prices[31]. However, they may be more appropriate in bi-modal seasonality contexts like Sri Lanka's, in which two rainy seasons and dry seasons occur each year. Model fit statistics were compared, and seasonal variation results are presented only for the stochastic trend model, which had the lower Akaike's Information Criteria test statistic.

The outcome variable in the stochastic trend model was the log of the first difference of the abbreviated CoRD. The first difference—or change in CoRD from one month to the next observed month—was used in order to achieve stationarity in the modeling, which better ensured accurate mean and variance estimates over the study period. The model was fit to allow for gaps in monthly data for a given location, which avoided the need for interpolation of these missing points. These methods follow closely the steps used by two previous studies into the seasonality of food prices and cost of diet[31,32]. Additionally, following *Schneider et al* (2021), the stochastic trend model was estimated first using only the data points where the abbreviated CoRD was feasible (i.e. where the variety requirements were satisfied for all FBDG except for dairy) and then, for comparison, again using data points where missing data was imputed using the maximum abbreviate CoRD observed for that month-year across all HARTI locations; this imputed method effectively treats an infeasible diet as the most expensive CoRD.

Seasonal variation was characterized in terms of the seasonal factors for each month, as well as the seasonal gap. Seasonal factors measure the percentage difference between the average CoRD for that month relative the average across all months (i.e., grand mean). The seasonal gap was then calculated as the difference between the maximum observed seasonal factor and the minimum seasonal factor. Models were fit separately to December 2014 – February 2020 and March 2020 – December 2021, to compare a typical seasonal pattern in CoRD to the pattern observed during Covid-19.

In addition to a comparison of the seasonal variation in CoRD prior to and during Covid-19, a comparison of the long-term trend in inflation-adjusted CoRD was attempted, again using a weighted non-food price index. A longitudinal model with a linear time trend and monthly dummies was fit to the data prior to Covid-19, accounting for within-location correlation with an auto-regressive correlation model, based on variogram evidence of rapidly decaying autocorrelation and comparison of model fit statistics. This model was then used to predict what a trend during March 2020 – December 2021 would have looked like based on the historical pattern, without Covid-19, which could then be compared to the actual data observed during Covid-19.

Results

Objective 1: Availability and cost of a healthy diet in the R5N area

Few gaps in the availability of a healthy diet were found in the R5N study area through July 2021 using the full definition of the GN food environment, which included the village retail shops sampled within the GN in addition to the two nearest traditional markets. As shown in **Table 5.2.**, a monthly average of 91% of study GNs offered sufficient variety of foods to satisfy FBDG during this period. In September 2021, only 62% of GNs could supply the necessary variety of foods, before increasing back to 80% in December 2021. Restricting the GN food environment definition to only the single nearest market (but still including the village retail shops) resulted in significantly larger availability gaps that began earlier in the year. Only 50% of study GNs supplied sufficient food items to for FBDG in March 2021 and in July 2021, a low of 28% of study GNs was reached.

Fruits, which require at least two unique items, and vegetables, which require three unique items including one green leafy vegetable, were the food group FBDGs with the largest, most frequent availability gaps. These both reached availability lows in September 2021. Dairy, which required just one unique item, was also unavailable in many GNs, especially from September until the end of the year. In contrast to fruits and vegetables, there was relatively little difference in availability for dairy items depending on the food environment definition (i.e. when restricting to just a single market).

Enumerators were not able to reach all of the traditional markets and retail shops during each month. Though 16 markets and 122 retail shops were initially sampled in December 2021, data collection visits could not take place when these markets or shops were closed due to Covid-19 restrictions. These were especially significant during May through August, during the Delta wave, however several areas experienced extended restrictions due to localized outbreaks. In September 2021, just 11 of the traditional markets could be visited. This likely impacted the feasibility of sourcing sufficient variety of foods for FBDG during that month. However, availability gaps were not only due to market and retail shop closures. **Appendix 3.1** shows that within the outlets that were reached by study enumerators, the total variety (i.e. count) of foods within various food groups was also declining. For many food groups, including fruits, vegetables, pulses, roots, and tubers, the widest variety in traditional markets was reached between February and April, which is also around the *maha* harvest. However, the month of lowest variety included approximately 30 – 40% fewer items for many of these food groups. Village retail shops also experienced declines in the average variety available of many food groups. The table also confirms the wider variety of fresh foods, especially fruits, vegetables, and fish, in markets relative to retail shops, but also pulses, roots, and tubers (albeit to a lesser extent), across all months.

The cost of a healthy diet in the R5N study area, measured as CoRD, increased by 25% from December 2020 (LKR 155 per person per day) to December 2021 (LKR 195 per person per day) after adjusting for non-food price inflation. In nominal terms, this represented an increase of 37%. As shown in **Figure 5.1**, the majority of this increase took place during the second half of the year, after July 2021, which was roughly aligned with the timing of a steep national increase in the CPI for food from 161 to 182 (base 2013 = 100) between September and December 2021.

Restricting each GN food environment to only the single closest traditional market (the red line in **Figure 5.1**) resulted in a higher cost CoRD, as well as a steeper trend beginning from September. This demonstrates that the convenience of using only the single closest traditional market for food purchases may come at a premium that grows larger as overall prices are increasing. However, it should also be noted that for many months, the single market CoRD calculation is based on a substantially smaller sample of GNs, as **Table 5.3** demonstrated that achieving the FBDG-recommended diet was not even feasible in many GNs if sourcing food from multiple markets was not considered. This likely explains the lower value of the single market CoRD versus the standard CoRD during March 2021; only 22 GN Divisions could supply sufficient variety for CoRD using just a single traditional market, compared to 43 GN Divisions when sourcing from two traditional markets, and those GN Divisions where the single market CoRD was infeasible may have been higher-cost food environments during a typical month. The monthly trend in CoRD did not conform to a clear theoretical pattern based on seasonality, which would have seen a lower cost CoRD during March through May, when grain, vegetable, and legume prices typically fall following the *maha* harvest, and again in September and

October following the *yala* harvest, with peaks in between. However, missing data during May, June, and August, could hide the true shape of what CoRD would have looked like.

Among the individual food groups, vegetables experienced the largest price increase in real terms (59%) from December 2020 to December 2021, with protein-rich foods (43%) and fruits (35%) also increasing substantially (under the standard two market-CoRD calculation). These individual group FBDG cost components of CoRD are displayed in **Appendix 3.2.** While the minimum dairy FBDG cost only increased by 11% from baseline to endline, its highest price took place during September, when it was 58 LKR per person per day for 1.5 servings, a 27% increase from July. The minimum cost of the starchy staple FBDG, which requires at least two different items and 8.5 servings, had a relatively smaller increase from December 2020 to December 2021 (19%), however, considering the large portion of Sri Lankan household's food budget that goes to rice, this could have disproportionate effects on food security and diet quality.

Objective 2: Comparing the changes in the cost of a healthy diet in the R5N area to a national average cost of a healthy diet

Comparison of the cost of a healthy diet between the R5N area and the national average, estimated from HARTI's national food price surveillance data, was based on the abbreviated CoRD measure. In December 2020, abbreviated CoRD was LKR 129 per person per day in the R5N area, LKR 26 lower than the December 2020 estimate for the full CoRD. This lower cost for the abbreviated CoRD was a result of its exclusion of dairy foods, which are not tracked by HARTI. The abbreviated CoRD calculation resulted in small increases for other food groups, including the vegetables FBDG (Full CoRD: LKR 35 vs. Abbreviated CoRD: LKR 40) and the protein foods FBDG (Full CoRD: LKR 18 vs. Abbreviated CoRD: LKR 22), and a larger increase in the starchy staple FBDG (Full CoRD: LKR 30 vs. Abbreviated CoRD: LKR 41).

These differences were due to the restricted food list, described in **Table 5.1.**, which limited the linear optimization options for identifying the lowest cost items to make up a healthy diet. For example, the larger difference in starchy staples was likely due to the absence of wheat flour in the food list used for the abbreviated CoRD, as HARTI does not monitor this item, nor other processed grains, though wheat flour, along with rice, were often the cheapest starches in the R5N GNs. Several of the small or absent differences in other food groups grew larger later in the year – for example, the difference between the full food list vs. abbreviated CoRD estimates for fruits and vegetables grew larger in March and April as compared December, perhaps indicating the increased importance of items not monitored by HARTI during primary harvest months.

The national average abbreviated CoRD in December 2020 was LKR 160 per person per day, 20% higher than in the R5N area. Several studies have noted higher prices in urban areas as compared to rural areas in LMICs, which could be especially true for unprocessed raw foods, which are transported from rural to urban areas[33,34]. Diet costs could also vary with income levels. A previous study in Sri Lanka found lower cost healthy diets to be most expensive in several of the wealthiest districts and on average cheaper in several of the poorest districts[35]. The R5N program is targeted to vulnerable communities with many low-income, food insecure households, so prices in local markets and shops could reflect the incomes of surrounding households.

The lower cost of a healthy diet in the R5N area relative to the national average in December 2020 was erased by the end of the study period, in December 2021. Average plots for the R5N area and the national HARTI data are shown in **Figure 5.2.**, which are adjusted for non-food CPI. The national average increased by 11%, from LKR 160 per person per day in December 2020 to LKR 179 per person per day in December 2021, however the increase in the R5N area was nearly three times as large over this period, rising by 28%, from LKR 120 per person per day to LKR 179 per person per day.

A generalized linear mixed model was used to explore further the differences in abbreviated CoRD trends between R5N and HARTI, while accounting for within-location correlation in the observed data. This model estimated that for each month of follow-up, abbreviated CoRD increased LKR 3.46 (95% CI: 2.66, 4.27) per person per day more in the R5N area relative to the HARTI national average.

Objective 3: Comparing changes in seasonal variation and trend of the cost of a healthy diet before Covid-19 and during Covid-19

Another question of interest was how changes in diet costs during the study period would compare to a typical seasonal pattern, prior to Covid-19. This analysis was conducted using data from HARTI's national food price surveillance system with eight years of data, from January 2014 to December 2021. Due to the limited period of data collection in the R5N area and several months when data collection was not possible, the R5N food environment data could not be incorporated in this analysis. Comparisons of seasonal variation and trend were made between HARTI abbreviated CoRD estimates during the time ranges of: a) January 2014 – February 2020 (pre Covid-19), and; b) March 2020 – December 2021 (Covid-19). March 2020 was chosen as the start of the Covid-19 era in Sri Lanka because this was when the first national lockdown was put in place, in addition to many of the import restrictions that were used to begin limiting outflow of foreign exchange.

Visual inspection of the averages plot from January 2014 to December 2021 provides limited evidence of a seasonal pattern in abbreviated CoRD (see **Figure 5.3**). However this trend, which was again adjusted for non-food CPI, showed more pronounced peaks and troughs during years 2015 and 2016, while 2014 showed no signs of seasonal variation, and 2017-2018 included a break in the trend that made seasonality difficult to assess. CoRD volatility did appear to increase beginning in 2020.

The stochastic trend model using monthly bivariate variables enabled further exploration of the average seasonal variation before and during Covid-19. This model was a better fit than the trigonometric model; a visual comparison of these models is shown in **Appendix 3.3**. Prior to running this model, the abbreviated CoRD outcome variable was log transformed and first-differenced. As explained by Gilbert, Christiaensen, and Kaminsky (2017), this assumes that the CoRD trend is stochastic, but difference stationary; therefore, the log change in nominal abbreviated CoRD was more appropriate for extrapolating sample statistics needed for estimating seasonal variation. Log differences also have the benefit of allowing interpretation as percent differences when the differences are not large.

Table 5.3 displays the separate seasonal variation results for the pre Covid-19 period (January 2014 – February 2020) and the Covid-19 period (March 2020 – December 2021). Columns (a) and (b) are estimated for these time period using only the diet cost estimates from markets and months where it was possible to satisfy the variety requirements of CoRD. Columns (c) and (d) are generated from a dataset where these missing values were instead imputed using the highest cost observed CoRD for that month.

Examination of the seasonal factors shows that the abbreviated CoRD did follow a seasonal pattern, albeit a weak one. Negative deviations from the grand mean, indicated by negative values, are somewhat clustered around harvest seasons. For example, on average during the January 2014 – February 2020 period, the month of February, at the beginning of the *maha* harvest, had 1.95% lower CoRD than the average CoRD over all months, based on seasonal factors estimated where CoRD was feasible (column A). Meanwhile in June, during the inter-monsoonal period, CoRD was on average 0.93% more expensive. However, this pattern is not clearly defined. In May, a month when CoRD should theoretically be less expensive following the *maha* harvest, it exhibited the largest percent increase.

The lack of a strong seasonal pattern could relate to a couple factors. First, that the timing and duration of Sri Lanka's monsoon seasons is highly variable from year to year. A study of rainfall data from 1981 to 2019 gathered from meteorological stations in Sri Lanka's dry zone found substantial inter-annual variation in the duration of the *maha* season, particularly due to variation in its termination date[36]. These patterns may also vary according to location, meaning that the extent of agricultural activities could be both temporally and spatially dispersed, resulting in muted variation in CoRD. Second, where individual foods may exhibit strong seasonal patterns based on the timing of rainfall, plantings, and harvests, a whole-of-diet measure like CoRD may not necessarily, due to the fact that different food items' seasonal patterns are not harmonized. There are differences both within food groups and across food groups, including some foods (e.g. animal source proteins and dairy) which affected by seasonality very little or not at all.

Comparing column C to column A in **Table 5.3** highlights the larger seasonal factors and seasonal gap when missing observations from markets where the CoRD diet was infeasible were imputed. February is still the lowest price month, but is 2.95% cheaper compared to 1.95%, and June was the most expensive month using imputed costs, at 2.77%, equating to a seasonal gap of 5.72%. The larger increase in June from column A to column C suggests that a larger number of markets were unable to offer sufficient variety of foods in that month relative to, for example, May, which changed relatively little. Omitting markets where it was not feasible to source sufficient foods for CoRD, as in column A, could induce a bias, as these are not missing at random, but rather missing due to a lack of low-priced, diverse foods.

The seasonal gap increased during Covid-19 relative to pre-Covid-19. When infeasible observations were left out of the data set, the seasonal gap was 119% larger during Covid-19 and when imputed, the seasonal gap was 127% larger. The typical seasonal pattern also appeared to be disrupted during Covid-19, which is especially noticeable in Column D, where there are several months of large percentage increases in the second half of the year—June, August, September, and December—with only October displaying any decrease in the cost of CoRD that would have been expected with the *yala* harvest. Columns B and D average together years 2020 (after February) and 2021, but it is likely year 2021 driving these increases, with the debt and foreign exchange crisis that was taking hold.

The study also intended to compare differences in the long-term trend of inflation-adjusted CoRD before Covid-19 and during Covid-19. A longitudinal linear model was fit to the abbreviated CoRD deflated by non-food CPI for the period of January 2014 – February 2020, including a time trend and monthly dummies to account for seasonal variation. This model was to be projected forward to the Covid-19 period to provide a glimpse of what the typical trend may have looked like without Covid-19, which could then be compared to actual observed data. However, cyclical variation in CoRD that was not anticipated by the model complicated this comparison. Other models introducing more flexible time parameters, such as a linear spline, were fit, but the variation in the trend between 2017 and 2020 was determined to be too unpredictable to allow for the extrapolation of a model-generated comparison for the February 2020 – December 2021 time period. These attempts are shown **Appendix 3.4.**

Discussion

This study set out to assess changes from December 2020 to December 2021 in the availability and cost of a healthy diet in rural areas of Sri Lanka where WFP is implementing a food assistance for assets program targeted to smallholder farmers. The key finding is that significant decreases in availability and increases in cost took place, which are likely to have restricted vulnerable households' access to a healthy diet. In September, only 62% of the 45 study GNs offered sufficiently diverse foods to meet recommendations in FBDG, and this was as low as 28% under a scenario where households do not spread food purchases over multiple traditional markets. After adjusting for non-food price CPI, the real cost of a healthy diet, measured using CoRD, increased by 25% over the study period, from LKR 155 per person per day in December 2020 to LKR 196 per person per day in December 2021.

Through comparison with national data from the Sri Lankan national food price surveillance system, the study also provided some evidence that increases in CoRD may have been more pronounced in remote, rural communities like where the R5N program is implemented relative to urban centers where the national surveillance system collects data. Using an abbreviated measure of CoRD that did not include dairy (due to the absence of dairy items in the national food price surveillance system), the R5N area experienced an increase in diet cost that was nearly triple the national average increase. This can be compared with research on food prices and Covid-19 from India, which found that initial price increases during the pandemic dissipated more rapidly in larger cities relative to smaller cities, perhaps due to more concerted efforts to stabilize supply chains in denser populated areas[37]. An examination of staple food prices in six African countries also consistently identified higher prices in rural areas as compared to urban areas during Covid-19, which were credited to multiple factors, including increased transport and transaction costs along supply chains as well as the stronger dampening effect of consumer demand in urban areas[38].

Though the study could not evaluate seasonal patterns of CoRD in the R5N area due to the limited time range of the study period and several months when data collection was not possible due to Covid-19 restrictions, analysis of national data indicates that there was an increase in seasonal variation during Covid-19 (March 2020 – December 2021) relative to a historical pattern, based on January 2014 to February 2020 data. This increased cost volatility could relate to lower availability of food during Covid-19, which would offer fewer low-priced substitution options to maintain a low-cost CoRD.

However, the typical seasonal effect on CoRD in Sri Lanka appears to be small. A comparable analysis in Malawi estimated a seasonal gap of 10%-14% in the cost of a nutritious diet, based on data where this diet was feasible, or 32%-116% when imputing the infeasible observations[32]. These seasonal gaps were 3-4 times higher than Sri Lanka's seasonal gaps using estimates where diets were feasible, or 6-20 times larger using imputed costs. This may provide only a crude comparison, however because that study analyzed a different cost of diet indicator, the cost of a nutrient adequate diet (CoNA), which estimates the minimum cost of meeting the specific nutrient requirements of individual household members and was calculated at the household level.

Food availability and affordability in R5N food environments deteriorated particularly after July 2021. The most pronounced real cost increases took place beginning in September, which was also the month with the greatest availability gaps. This timing was aligned with key turning points in Sri Lanka's foreign exchange crisis, for example, when an economic emergency was declared in August 2021 and when food CPI took a steep turn upwards in September 2021, as evident in **Figure 2.2**. The contribution of this chapter to those national developments has been to: a) confirm that the food shortages and price increases reported in news media, typically focused in urban areas such as Colombo, were also felt in remote rural areas of Sri Lanka; and b) to show that the cost of a healthy diet was not resilient to these changes, i.e. substitution effects among different foods within food groups were insufficient to maintain a low CoRD in the face of overall food price inflation.

This study is constrained by several limitations. First, missing data during months of Covid-19 restrictions preclude a fuller view of the monthly changes in CoRD in the R5N area. It is hoped that national food price surveillance accessed, which was available for these months, will fill in these gaps to some extent. Second, no spatially disaggregated CPI estimates were available for Sri Lanka. If there were differences in prices changes for non-food items between rural and urban areas during this period, it could bias the comparison of the adjusted R5N CoRD trend versus the national trend. Finally, it was not feasible within the design and scope of this study to attribute effects on food availability and cost to individual macroeconomic or Covid-19 related drivers. Disentangling these factors would benefit from additional data related to how exposures to Covid-19 restrictions or other policies varied across geographic areas. For example, the large cost increase in vegetables documented in this study relative to other food groups could relate to the fertilizer ban, which reportedly reduced vegetable yields during the *yala* harvest, but attribution of this cost increase to the ban (as opposed to import restrictions, fuel price inflation, etc.) would require a more complex study design, with access to data on how fertilizer usage varied across different market catchment areas of the country.

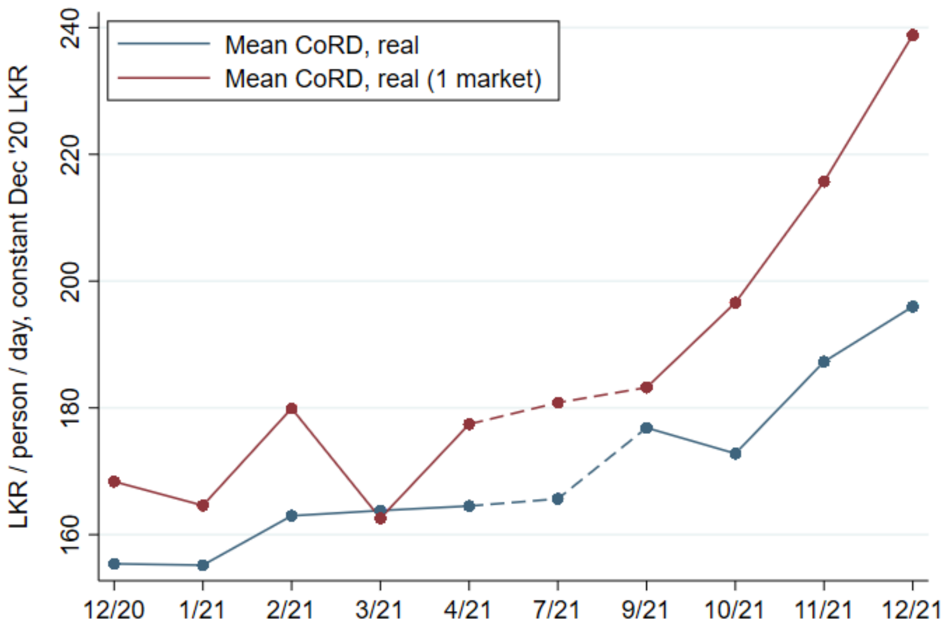
Previous food environment research has tended to utilize cross-sectional designs. A strength of this study is the ability to track changes over the course of a year, during a period of shocks. Additionally, scant research has been conducted in rural area of LMICs, where traditional markets operate sporadically and may be difficult to reach. Through comparison with a national data set, it has been shown that food environments may respond differently to shocks in these areas relative to urban areas, and therefore may warrant special attention in the form of policy and program responses. Some of these types of policies have already been considered by the Sri Lankan government – for example, early during the pandemic, home gardens were promoted as a means of protecting food security.

By embedding regular monitoring of the food environment within a program impact evaluation, the study has also generated contextual information to inform barriers that program activities may be confronted with in achieving their stated objectives. The R5N program has aimed to improve resilience among smallholders through a production-oriented pathway that is based on improving access to water, then yields, and finally increasing agricultural sales and income. These activities could also improve diets, but especially in the face of increased diet costs, the WFP approach of adding nutrition-sensitive activities, including behavior change communication and small livestock rearing, strengthens this likelihood. Future research-implementation partnership activities could seek to incorporate food environment monitoring directly in messaging activities, for example by promoting lower-priced food items or recipes that would generate cost savings while contributing to healthy diets, or by intensifying transfers to stabilize purchasing power during shocks.

Conclusion

Though food availability and the cost of a healthy diet in the R5N area likely posed few barriers to local consumers' access during December 2020, these barriers became more substantial especially during the second half of 2021. Food environments in rural Sri Lanka have been negatively affected by the national foreign exchange and debt crisis; while food scarcity and food price inflation have been widely reported, this study confirmed and quantified that the minimum cost of a healthy diet has not been resilient to these changes, and that rural areas may have possibly experienced more dramatic erosion of affordability. Seasonality is the cause of inter-annual variation throughout the year, however, analysis of secondary national data would indicate that it cannot explain the large volatility in the cost of a healthy diet during Covid-19 alone. To some extent, households can mitigate their exposure to higher food prices by spreading food purchases over multiple markets; however, policy and program responses are likely needed to ensure vulnerable rural households can cope with these shocks.

Figure 5.1. Mean Cost of the Recommended Diet (CoRD) in 45 rural GN Divisions in the R5N study area, by month of follow-up



Note: Dashed lines indicate missing months of data collection (May, June, August)

Figure 5.2. Abbreviated cost of the recommended diet (CoRD) in the R5N area vs. HARTI food price surveillance data national average, December 2020 – December 2021

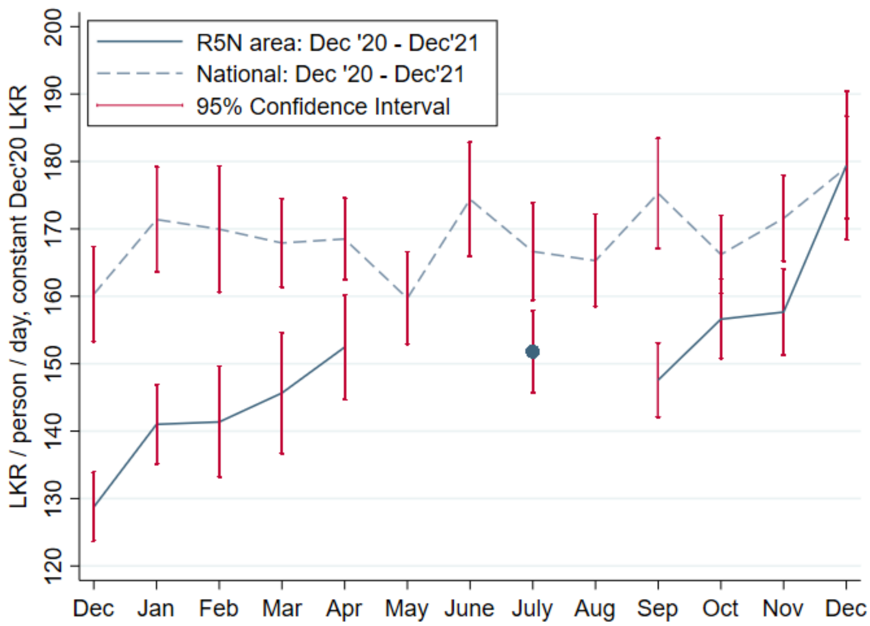


Figure 5.3. Abbreviated cost of the recommended diet (CoRD) in HARTI food price surveillance markets, January 2014 – December 2021

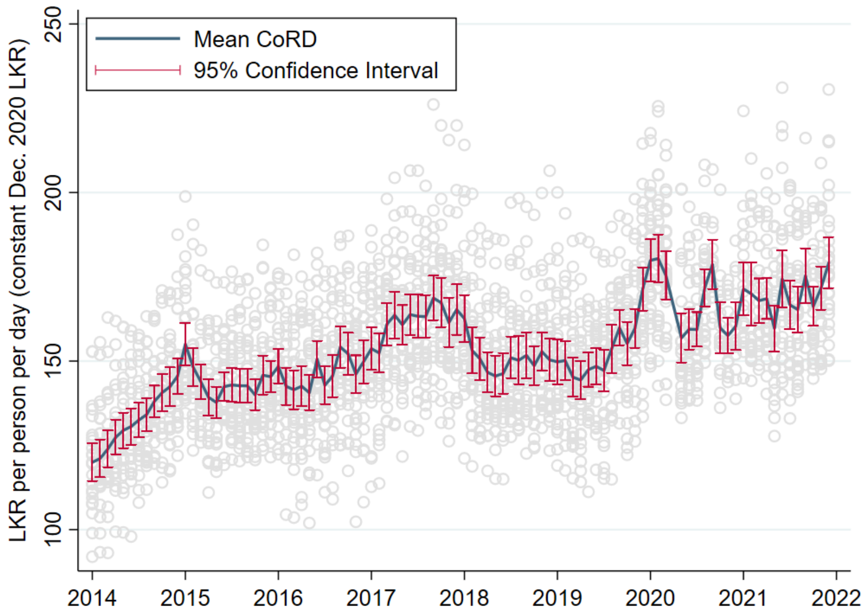


Table 5.1. Comparison of R5N and HARTI food lists

	Total unique items included in survey food lists:	
	R5N	*HARTI*
Fruit	22	11
Vegetables	32	19
Green leafy vegetables	10	3
Pulses	14	4
Fish	41	18
Meat	11	5
Eggs	2	2
Grains	15	1
Roots and tubers	7	5
Milk and dairy	6	-
Nuts	5	1
Oils	10	-
TOTAL	175	69

Table 5.2. Availability of sufficient food variety for FBDG in study GNs, as a percent of total GNs, by month of follow-up

	Dec '20	Jan '21	Feb '21	Mar '21	Apr '21	Jul '21	Sep '21	Oct '21	Nov '21	Dec '21
Outlets surveyed:										
Number of markets	16	16	16	16	16	15	11	14	14	16
Number of shops	122	121	110	105	119	120	118	120	119	121
FBDG feasibility:										
Utilizing two markets										
Fruit	93%	98%	96%	96%	98%	91%	73%	91%	96%	100%
Vegetables	100%	91%	93%	100%	100%	98%	89%	93%	93%	100%
Protein foods	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Starchy staples	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dairy	91%	100%	93%	100%	98%	98%	78%	84%	80%	80%
Nuts & oils	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
All FBDG	84%	89%	87%	96%	98%	91%	62%	76%	73%	80%
Utilizing one market										
Fruit	85%	74%	80%	74%	76%	68%	54%	83%	85%	87%
Vegetables	91%	76%	85%	72%	89%	83%	52%	83%	83%	89%
Protein foods	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Starchy staples	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Dairy	91%	100%	93%	87%	96%	98%	72%	83%	80%	78%
Nuts & oils	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
All FBDG	78%	61%	76%	50%	72%	66%	28%	70%	67%	70%

Legend:	100%	89%	78%	67%	56%	44%	33%	22%	11%	0%

Percent of GN Divisions (n=45) where FBDG was feasible

Table 5.4. Seasonal variation in the cost of the recommended diet (CoRD), pre- and during Covid-19

		Seasonal factors *Where feasible*		Seasonal factors *Imputing if infeasible*	
Month	**Cultivation seasons**	**(a) Pre Covid-19** Jan '14 – Feb '20	**(b) Covid-19** Mar '20 - Dec '21	**(c) Pre Covid-19** Jan '14 - Feb'20	**(d) Covid-19** Mar '20 - Dec '21
January		0.61	0.19	0.43	1.86
February	*maha harvest*	-1.95	-1.26	-2.95	-7.35
March	*maha harvest*	0.00	-1.28	-0.25	-5.85
April	*maha harvest*	1.11	0.92	0.09	-2.54
May		1.47	-0.85	1.51	0.51
June		0.93	3.28	2.77	3.88
July		-0.53	0.45	-0.10	0.89
August	*yala harvest*	0.78	2.88	1.08	5.28
September	*yala harvest*	-0.10	0.24	-0.54	3.03
October	*yala harvest*	-2.00	-4.28	-2.34	-7.69
November		-0.41	0.07	-0.01	2.94
December		0.08	-0.38	0.32	5.04
	Seasonal gap	**3.46**	**7.57**	**5.72**	**12.97**

References

1. Headey, D. D. & Alderman, H. H. The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents. *J. Nutr.* (2019) doi:10.1093/jn/nxz158.

2. Miller, V. *et al.* Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet. Global health* 4, e695-703 (2016).

3. Drewnowski, A. & Specter, S. E. Poverty and obesity: The role of energy density and energy costs. *American Journal of Clinical Nutrition* vol. 79 6–16 (2004).

4. Cornelsen, L. *et al.* What Happens to Patterns of Food Consumption when Food Prices Change? Evidence from A Systematic Review and Meta-Analysis of Food Price Elasticities Globally. *Health Econ.* 24, 1548–1559 (2015).

5. Brinkman, H.-J., de Pee, S., Sanogo, I., Subran, L. & Bloem, M. W. High Food Prices and the Global Financial Crisis Have Reduced Access to Nutritious Food and Worsened Nutritional Status and Health. *J. Nutr.* 140, 153S-161S (2010).

6. Bai, Y., Alemu, R., Block, S. A., Headey, D. & Masters, W. A. Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. *Food Policy* 99, 101983 (2021).

7. FAO, IFAD, UNICEF, WFP, and WFP. *The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets*. (2020).

8. Cost of Nutritious Diets Consortium. *Indicators and tools for the cost of nutritious diets*. (2018).

9. Carducci, B. *et al.* Food systems, diets and nutrition in the wake of COVID-19. *Nature Food* 2, 68–70 (2021).

10. Béné, C. *et al. Impacts of COVID-19 on People's Food Security: Foundations for a more Resilient Food System*. (2021).

11. Bogmans, C., Pescatori, A. & Prifti, E. Four Facts about Soaring Consumer Food Prices. *IMFBlog* https://blogs.imf.org/2021/06/24/four-facts-about-soaring-consumer-food-prices/ (2021).

12. Baffes, J. & Temaj, K. Food prices continued their two-year-long upward trajectory. *World Bank Blogs* https://blogs.worldbank.org/opendata/food-prices-continued-their-two-year-long-upward-trajectory (2022).

13. Thowfeek, R. Sri Lanka's dilemma: Pay off debt or pay for milk, meds and gas. *Al Jazeera* (2022).

14. Aneez, S. As food and energy prices soar, Sri Lankans go without. *Al Jazeera* (2021).

15. News Agencies. Sri Lanka allows sharp rise in food prices to ease shortages. *Al Jazeera* (2021).

16. Verité Research releases results of island-wide farmers' survey on fertiliser ban. *Verité Research* https://www.veriteresearch.org/2021/08/25/verite-research-releases-results-of-island-wide-farmers-survey-on-fertiliser-ban/ (2021).

17. Wipulasena, A. & Mashal, M. Sri Lanka's Plunge Into Organic Farming Brings Disaster. *The New York Times* (2021).

18. Deaton, A. Getting Prices Right: What Should Be Done? *Journal of Economic Perspectives* 12, 37–46 (1998).

19. Tendall, D. M. *et al.* Food system resilience: Defining the concept. *Global Food Security* 6, 17–23 (2015).

20. Bai, Y., Naumova, E. N. & Masters, W. A. Seasonality of diet costs reveals food system performance in East Africa. *Science Advances* 6, (2020).

21. Gunaratne, M. S., Radin Firdaus, R. B. & Rathnasooriya, S. I. Climate change and food security in Sri Lanka: towards food sovereignty. *Humanities and Social Sciences Communications* 8, 1–14 (2021).

22. Eckstein, D., Künzel, V., Schäfer, L. & Winges, M. *Global Climate Risk Index 2020: Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018*. www.germanwatch.org/en/cri (2019).

23. Dizon, F., Herforth, A. & Wang, Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security* 21, 38–51 (2019).

24. Kaminski, J., Christiaensen, L. & Gilbert, C. L. Seasonality in local food markets and consumption: evidence from Tanzania. *Oxford Economic Papers* 68, 736–757 (2016).

25. Zant, W. How Is the Liberalization of Food Markets Progressing? Market Integration and Transaction Costs in Subsistence Economies. *Oxford University Press* (2013) doi:10.1093/wber/lhs017.

26. Department of Census and Statistics. *Bulletin of Selected Retail and Producer Prices, 2016 - 2019*. (2020).

27. Department of Census and Statistics. *Household Income and Expenditure Survey, 2016*. (2018).

28. Liyanage, N. V. R. Behind the curtains of pola: Creating and negotiating local markets in Sri Lanka. (Ball State University, 2016).

29. Jayatillake, P. J. & Mahalianaarachchi, R. P. Behavioral pattern of fruit & vegetable consumers in the 'Pola' (Fair) system in Monaragala district in Sri Lanka. *Jiangsu nong ye xue bao* 3, 33 (2007).

30. International Monetary Fund. Consumer Price Index (CPI). *IMF Data* https://data.imf.org (2022).

31. Gilbert, C. L., Christiaensen, L. & Kaminski, J. Food price seasonality in Africa: Measurement and extent. *Food Policy* 67, 119–132 (2017).

32. Schneider, K., Christiaensen, L., Webb, P. & Masters, W. A. *Assessing the Affordability of Nutrient-Adequate Diets*. https://openknowledge.worldbank.org/handle/10986/36485 (2021).

33. Majumder, A., Ray, R. & Sinha, K. Calculating rural-urban food price differentials from unit values in household expenditure surveys: A comparison with existing methods and a new procedure. *American Journal of Agricultural Economics* 94, 1218–1235 (2012).

34. Gaddis, I. *Prices for Poverty Analysis in Africa*. http://dx.doi.org/10.1596/1813-9450-7652 (2016) doi:10.1596/1813-9450-7652.

35. Dizon, F. & Herforth, A. *The Cost of Nutritious Food in South Asia. Policy Research Working Paper 8557*. http://www.worldbank.org/research. (2018).

36. Ampitiyawatta, A. D., Nilmalgoda, E. P. R. H. H. W. & Wimalasiri, E. M. A Gaussian model approach to determine the commencement, termination and length of the major growing season over the dry zone of Sri Lanka. *Theoretical and Applied Climatology* 148, 739–750 (2022).

37. Raghunathan, K. The evolution of food prices during the COVID-19 pandemic in India. (2022).

38. Yade, M. *et al.* The Impact Of COVID-19 On Staple Food Prices: Location Matters. in *2021 Annual Trends and Outlook Report: Building Resilient African Food Systems after COVID-19* (eds. Ulimwengu, J. M., Constas, M. A. & Ubalijoro, É.) 25–45 (Akademiya 2063 and IFPRI, 2021).

Chapter 6. The influence of the food environment on dietary patterns in rural Sri Lanka: Testing associations between food availability, cost of a recommended diet, and dietary diversity among smallholder farmers

Abstract

Diversifying diets is a means for low and middle-income countries (LMICs) to work towards preventing undernutrition and reducing diet-related non-communicable diseases (NCDs) simultaneously, both important goals in the context of the double burden of malnutrition. Smallholder farmers are an especially key target group, as they are among the world's most vulnerable to food insecurity. Previous research has shown market access to be a more powerful determinant of dietary diversity among smallholder households than food crop diversity in most contexts, but often little is known about the quality of food environments in the types of markets where smallholders acquire food. Sri Lanka is an LMIC where income inequalities and vulnerability to climate shocks place smallholders' livelihoods and nutritional status at risk. This study assessed the associations between two food environment characteristics—food availability and cost of the recommended diet (CoRD)—and dietary diversity among 1,185 smallholders in rural Sri Lanka residing in 45 Grama Niladhari Divisions (GNs), by merging food availability and price data gathered from local open-air traditional markets and village retail shops with diet data gathered from 24-hour recalls. Data were gathered between December 2020 and February 2021 using in-person audits in markets and retail shops, and phone interviews for dietary data and other household characteristics. Multilevel Poisson regression with GN random intercepts was used to assess the associations of GN-level food availability and cost of diet with a ten-food group dietary diversity score (DDS). Neither food availability nor CoRD were significantly associated with DDS after adjusting for household and individual-level covariates. Within-GN variance in DDS was substantially greater than between-GN variance and in general, individual and household level covariates that could explain this within-GN variance were more significant. Sri Lanka has continued to experience dramatic economic

shocks related to Covid-19 and its foreign exchange crisis, which have impacted food security and food prices. Future analysis will re-examine food environment-diet associations while incorporating longitudinal data.

Introduction

Poor diet quality is a leading risk factor in the global burden of disease[1,2]. In low and middle income countries (LMICs) in particular, inadequate and imbalanced diets contribute both to undernutrition—including stunting, wasting, and micronutrient deficiencies—as well as a growing burden of non-communicable diseases (NCDs)[3]. Without an acceleration in diet quality improvements, achieving the Sustainable Development Goal (SDG) of ending malnutrition in all its forms by 2030 may not be possible.

Dietary diversity is associated with nutrient adequacy, an important dimension of diet quality. Food group diversity indicators, measured as simple counts, have been shown to predict micronutrient adequacy among adult women and men[4,5]. Consuming a variety of foods is also a nearly universal recommendation in national food based dietary guidelines (FBDGs)[6]. However, adhering to FBDGs may be challenging in resource-limited settings, due not only to individual-level factors (e.g., low income, nutritional knowledge, time constraints, etc.) but also constraints in local food environments.

Food environments are the interface between consumers and the broader food system, where people choose and acquire foods[7]. Food environments that restrict access to healthy foods could lead to disparities in health outcomes. Though the linkages between food environments, diet quality, and nutritional status has been studied more extensively in high income countries, in LMICs, this literature is still growing[8]. Findings to date have shown food availability to be associated with diet outcomes at the community-level, though in general, conclusive evidence on food environment-diet linkages has been lacking. This is in part due to the nascent state of methods for assessing food environments, which lack standardized instruments and metrics[8,9].

Food prices and affordability are dimensions of the food environment that have received much attention in the previous several years, including the development of new indicators focused on characterizing dietary costs[10–12]. Nutritious diets have been shown to be unaffordable in LMICs[12–15]. Research has shown that the cost of two daily servings of fruit and three servings of vegetables alone would cost 18% of total household income[16]. Cost-related barriers to healthier diets have also been identified in socio-anthropological studies, where low-income consumers reported economic factors as a leading deterrent to purchasing more nutritious food[17–19]. It has been estimated that at least 57% of the population in Sub-Saharan Africa and South Asia cannot afford the cost of a recommended diet (CoRD), one of the recent diet cost indicators to have emerged, which measures the minimum cost of adhering to FBDGs[12]. While indicators such as CoRD have provided strong advocacy for monitoring and surveilling food prices and access to healthy diets, their usefulness in community-level research into the linkages between food environments and diet outcomes is not yet established.

Sri Lanka is an LMIC that is facing a double burden of malnutrition. Among adults, persistent anemia among pregnant women and rising overweight and obesity among men and women are of particular concern [20–22]. Though large-scale dietary surveys have not been conducted in Sri Lanka, small-scale studies and rapid assessments have indicated that over 70% of adults consume less than the globally recommended 400 grams of fruits and vegetables daily, while consumption of starchy staples exceeds the dietary recommendations for 85% of men and 61% of women[23,24]. One study among 400 women of reproductive age residing in marginalized communities of Sri Lanka found that 62% of them did not consume minimally diverse diets[25].

Smallholder farming households are among the most vulnerable to food insecurity globally[26]. This is also true in Sri Lanka, where the bulk of the poor are rural-based agricultural workers. Furthermore, Sri Lanka is among the most vulnerable countries to climate shocks—especially droughts and floods—which threaten agriculture-based livelihoods[27]. When faced with such shocks, households that spend a large percentage of their income may reduce the quality or even quantity of the food they consume, for lack of alternative coping mechanisms[28]. Recognizing this vulnerability, nutrition-sensitive agriculture approaches like crop diversification and homestead food production, among others, aim to improve food access and diets among smallholders via an own production-own consumption pathway[29,30]. However, a meta-analysis of studies examining crop diversity and dietary diversity linkages found their association to be weak, especially relative to market access, which has a stronger association with dietary diversity[31]. Still, rural food environment contexts where smallholders acquire foods are underrepresented in the food environment literature, which has focused more on cities and urban consumers[8,32].

There are reasons to believe the availability and affordability of nutritious foods may be limited in rural areas of Sri Lanka. In the northern provinces, market and agricultural infrastructure is still being rehabilitated after sustaining heavy damages during the Sri Lankan civil war, which lasted until 2009. Poor roads could make it difficult to distribute foods to rural areas, especially where cold chains are not available for storage. Nationally it has been estimated that 54% of Sri Lankan's cannot afford a healthy diet (based on CoRD), though this is higher in many predominantly rural districts[12,33,34]. However, studies linking food environment metrics to describe food availability and food affordability with diet outcomes in Sri Lanka are not available. Additionally, little is known about how the Coronavirus 2019 Disease (Covid-19) may have affected food environments in rural areas and their influence on diets.

This study tested associations between two food environment exposures—CoRD and food availability—and dietary diversity among 1,185 study participants from smallholder farming families in rural Sri Lanka, during December 2020 – February 2021. Specific hypotheses tested were that CoRD would be inversely associated with dietary diversity, while food availability (measured as the total variety of foods available) would be positively associated with dietary diversity, while controlling for other individual, household, and community-level covariates. Twenty four-hour dietary recalls were conducted among the participants, with additional information on socio-demographic, economic, and agriculture-related factors gathered through household surveys. These data were merged with food environment data collected from market surveys in open-air, traditional markets and village retail shops in the 45 Grama Niladhari Divisions (GNs) where the study took place, including food prices and food availability.

This food environment research is a sub-study within the R5N impact evaluation, led by the International Food Policy Research Institute (IFPRI), which is evaluating the impacts of a World Food Programme (WFP) food assistance for assets intervention on diet and income outcomes among smallholder farming families vulnerable to climate shocks. WFP's intervention (the R5N program) aims to build resilience among smallholders through a combination of community and household-level irrigation infrastructure rehabilitation, agricultural training, and cash transfers, with a health education component added to enhance the program's contribution to nutrition outcomes. Evidence from this sub-study is intended to shed light on the food environment context in which the R5N program is implemented, which may affect the adequacy of the program to produce the intended income and diet outcomes, while also furthering knowledge of food environment-diet linkages in rural Sri Lanka, where such evidence is limited.

Methods

Study setting and design

This study used a multi-level, cross-sectional design to assess the impacts of food environment exposures on dietary diversity among participants in the R5N impact evaluation. The study area, including a total of 45 GNs, was spread across five rural districts of Sri Lanka: Batticaloa, Mannar, Matale, Monaragala, and Mullaitivu. Within each district, the study GNs were further concentrated within one District Secretary (DS) Division[j]. The study setting was determined by the targeting of WFP's R5N program, which first took consideration of geographic vulnerability to climate shocks, specifically droughts and floods, the key climate-related causes of lost income among farmers, and thus focused the program in the agro-ecological dry zone. Livelihoods in the study areas are largely dependent on paddy rice, with yields limited by access to training and technology, as well as water availability. Many smallholders grow rice only during the primary rainy season (*maha*) and during the secondary season (*yala*), grow less water-intensive lowland vegetables or other field crops (e.g., chili, onion, potatoes, legumes). Other field crops are especially common in Monaragala, which is more dependent on rainfed agriculture due to historically limited irrigation infrastructure, however damaged irrigation infrastructure from the civil war also limits water access in the northern districts of Mannar and Mullaitivu[35]. Many households also own livestock or engage in inland fishing, though these are mainly to supplement household consumption, not major commercial activities.

Further targeting of districts and DS Divisions identified areas of high poverty, vulnerability to food insecurity, and malnutrition. Batticaloa, Matale, and Monaragala have around 20% of their population living below the national poverty line, while in Mullaitivu 45% are living below the national poverty line, the highest in the country[36]. Though Mannar has a poverty headcount of only 8% (compared to the national average of 14%), pockets of poverty remain in former conflict-affected areas. Mannar and Batticaloa have among the highest prevalence of child stunting in the country (21% of children under five years of age each), and Monaragala and Mullaitivu are the two districts with the highest prevalence of child wasting (25% and 22% of children under five years of age, respectively)[37].

The R5N impact evaluation, which this research is a sub-study of, used a GN- and household-matched control trial design, wherein the 45 study GNs were each assigned to one

[j] GNs are the smallest administrative unit in Sri Lanka, each consisting of an average of 3 to 7 villages, while DS Divisions are the administrative unit between GN and district.

of three study arms: 1) 15 GNs that received the R5N program (irrigation system rehabilitation, training, and cash transfers) plus the health education intervention; 2) 15 GNs that received the R5N program only; and 3) 15 control GNs. WFP and the Government of Sri Lanka had already selected 30 GNs to receive the R5N program prior to the study inception. Fifteen of these 30 GNs were then randomly assigned to receive the additional health education and then 15 control GNs were selected from GNs in the same DS Division that shared similar socio-economic characteristics. With this sub-study taking place at baseline, prior to the implementation of R5N and health education activities, it was not expected that program participation would modify food environment exposure-diet associations, though future research will examine this question further.

Food environments were measured at the GN-level, with each study participant surveyed within a GN linked to the food environment that was defined for that GN. This definition included the two nearest, most frequently used traditional markets to each GN, and typically three (though in some cases one or two) village retail shops that were surveyed within each GN. Using this design, the overall aim of the study was to test for associations between food availability and dietary diversity (expecting this would be a positive association), as well as CoRD and dietary diversity (expecting this would be an inverse association, while adjusting for individual-, household-, and area (GN)- level covariates.

Sampling and survey procedures

Household and dietary surveys were led by IFPRI for the purposes of the R5N impact evaluation and shared for use in this food environment sub-study. Sampling and survey procedures for the study were adapted due to restrictions imposed by Covid-19 in 2020, requiring that the household and diet surveys be conducted through phone interviews. All R5N and health promotion beneficiaries in the 30 treatment GNs were contacted using beneficiary lists with phone numbers that were provided to IFPRI by WFP. Households in the 15 control

GNs were randomly selected from the most recent electoral lists (from 2016), using population-based sampling. The only exclusion criteria imposed was for households that were not engaged in agricultural activities and for individuals that were not yet 18 years of age. Interviews were conducted with the household member that was enrolled in the WFP intervention in the case of the treatment arms, while in the control arm, enumerators identified the household member that was most involved in agricultural activities. Prior to beginning data collection, enumerators read an informed consent statement and proceeded with interviews among participants who verbally consented to participate.

The household survey was divided into three separate phone calls, each lasting around 25 minutes, which assessed household demographics, expenditures (food and non-food), household assets, food security, agriculture, among other characteristics. Expenditure data was collected as a proxy measure of household income. Food expenditure was assessed for a pre-defined list of 135 items, with participants reporting the quantity of each item consumed over the previous 7 days. These quantities were then linked with price data from market surveys to estimate expenditure. Non-food expenditures were reported as the quantity of expenditure on a standardized list of items and services (e.g., health and education) over the previous 30 days. Food security was assessed using the Food Insecurity Experience Scale (FIES). Agriculture data collected included the size of agricultural land holdings, agricultural earnings over the previous year, and more detailed information about planting and harvesting activities for the household's four most important crops.

Dietary surveys consisted of an open 24-hour dietary recall that utilized three passes. In the first pass, a quick list of foods and beverages consumed the previous day was assembled. The second pass consisted of a description of each food and the portion size consumed. The third pass was a final check to ensure that no items were left out. Due to the need to keep phone interviews short, in lieu of collecting recipe information for mixed dishes during the interview, a database of standard recipes was compiled. Portion size estimates were based on locally used utensils and food piece types, sizes, or counts, which the respondent selected verbally. Dietary surveys were conducted among the same household member participating in the household survey.

Food environment data was possible to collect in person and was done using vendor audits in traditional markets and retail shops, which were conducted by enumerators from the University of Peradeniya. A purposive sampling approach was used to select the markets and retail shops to include in the food data collection. This relied on input from local stakeholders, including WFP field officers based in each of the five districts and village leaders in each of the GNs. For the market sample, the main markets used by households in each of the 45 study GNs were identified. There was no requirement for markets to be located within the GN's administrative boundaries. Study areas were contained within a relatively small portion of each district, so in most cases, markets included in the sample were utilized by multiple study GNs. Village leaders also indicated the names and locations of the three most frequented village retail shops within each study GN. In a few cases, less than three shops operated in GN, while in others, thirty or more shops were in operation. Three retail shops were sampled with consideration to budget and time constraints of enumerators, not based on representativeness.

Separate questionnaires were developed for traditional markets and retail shops and programmed for mobile data collection using the SurveyCTO platform. Both questionnaires assessed background characteristics and features of the market or shop (e.g., size, type of covering, access to refrigeration), followed by the availability and prices of a pre-defined food list. Food items included in the food list were identified using the Sri Lanka Household Income and Expenditure Survey 2016, which listed foods purchased by households, and the food list adopted by the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI), the primary government agency responsible for collecting and analyzing agricultural market information[38]. There were a total of 175 unique items included in the food lists.

Data was collected monthly from traditional markets and village retail shops during December 2020, January 2021, and February 2021, the three months during which the dietary and household baseline surveys were conducted. For the purposes of this food environment-diet analysis, each study participant was linked to the GN food environment where they resided using price and availability data for the month in which they participated in the 24-hour dietary recall.

Research protocols for household, dietary, and market data collection were approved by Wayamba University of Sri Lanka Ethics Review Committee and the International Food Policy Research Institute (IFPRI) Institutional Review Board. Household and diet survey enumerators were provided ethics training for phone interviews, while market enumerators were also given ethics training, including how to manage interactions with vendors courteously, without interfering with their transactions, and to take safety precautions for Covid-19. Additionally, permission from District Secretariat (DS) Division authorities was attained for the food environment sub-study and vendors were given the opportunity not to participate.

Outcome variables

The primary outcome of interest was a dietary diversity score (DDS) based on ten food groups, which ranged from 0 to 10. This score represented the count of unique food groups that the respondent consumed from in the previous day. Foods reported in the dietary recalls were categorized into the ten mutually exclusive food groups, which matched the food groups utilized in the Minimum Dietary Diversity for Women (MDD-W) indicator[39]. These included: 1) grains, white roots and tubers, and plantains; 2) pulses; 3) nuts and seeds; 4) dairy; 5) meat, poultry, and fish; 6) eggs; 7) dark green leafy vegetables; 8) other vitamin A-rich fruits and vegetables; 9) other vegetables; and 10) other fruits. Additional food groups were also tracked, but not included in the DDS, including condiments and seasonings, in order to ensure that consumption of small quantities did not factor into the DDS. Exclusion of quantities less than 15 grams has been shown to increase correlation between dietary diversity scores and probability of nutrient adequacy among women[5]. In this analysis, the same DDS is used for men and women.

Food environment exposure variables

Food availability was assessed at the GN-level as the total count of unique food items that could be found by enumerators in the two traditional markets and the village retail shops linked to each GN. The maximum possible was 175 food items, though the pre-defined food list included many seasonal items that were not available during December 2020 through February 2021. This count did not include duplicate items, such as different varieties of rice or mangos, however, different processing methods of the same fish species (fresh/unprocessed, dried, or canned) were counted as different food items, as was rice in flour or noodle form versus raw rice.

There are currently no standardized indicators of market food diversity[40]. A market diversity index (MDI) is under development, though previous versions of this have weighted each item by the proportion of total sales from the market that it represented, following Shannon diversity index-type methods that aim to account for evenness in addition to diversity[40,41]. This information was not possible to collect in the current study. Another study assessed market food diversity using a key informants-based approach to measuring food availability rather than vendor audits[42].

The cost of a healthy diet was measured using the CoRD indicator, adapted from the FAO *SOFI* report and Dizon and Herforth (2019), which utilized methods devised as part of the Tufts University-led Changing Access to Nutritious Diets in Africa and South Asia (CANDASA) initiative[12,14]. This indicator evolved from earlier diet cost indicators that examined the cost of dietary diversity and or nutrient adequacy[10]. CoRD measures the minimum cost of following FBDG (in Sri Lankan Rupees (LKR) per person per day), by selecting the lowest cost items within each food group, ensuring the variety requirements detailed in **Table 3.2.**, and taking the median number of recommended servings (e.g., 4 servings per day of vegetables). More detailed methods for estimating CoRD were described in *Chapter 3*.

CoRD was assessed at the GN-level using the lowest price items that were surveyed in the traditional markets and retail shops linked to each GN. This sourcing of lowest cost items from multiple food outlets was an attempt to mimic the shopping behavior of rural consumers, which based on preliminary review and interviews with key informants, was described as utilizing multiple outlets for different purposes (e.g. impromptu purchases versus planned weekly grocery shopping) and to procure the freshest, lowest cost items[43,44].

Individual and household covariates

A series of additional individual and household-level covariates was included in the analysis to increase the precision and reduce bias in the estimated association of food environment exposures and dietary diversity. These included socio-demographic variables, such as the study participant's age, sex, years of education completed, and household size. Economic factors included were the total household expenditure (LKR per person per day) and the household's socio-economic status (SES) quintile. The SES variable was constructed by IFPRI using principal components analysis, based on building materials used in walls, ceiling, and floor of home; number of rooms in home; ownership of home; electricity; ownership of household appliances and valuables; ownership of vehicles; and ownership of agricultural equipment. A binary variable indicating whether or not the household was moderately or severely food insecure (vs. not food insecure or minimally food insecure) was generating using an FIES raw score cutoff of 4 or greater (out of a total of 8 items). Finally, agricultural land holding was measured as the quantity in hectares of all plots of land owned by the study participant's household.

Regression analysis

Multilevel Poisson regression was used to test associations between food environment exposures and dietary diversity. In this model, individual study participants (level 1) were nested within GNs (level 2) and GN random intercepts were used to account for the clustering of standard errors within GNs. Only one member from each household was included in the dietary survey, therefore there was no need to account for within-household clustering.

The primary outcome—dietary diversity—was analyzed as a count variable. Both of the food environment exposures were analyzed as continuous variables, food availability measuring the total number of unique foods found in a GN and CoRD measuring the minimum cost of a healthy diet in LKR per person per day. Though food availability could have also been treated as a count, because of the lack of zero values and the relatively high number of foods available in most GNs, it was considered as continuous. In order to test associations between food environment exposures (level 2 variables) and dietary diversity while adjusting for individual and household (level 1) covariates, GN-mean covariates were calculated and included in the multi-level model. These represented the composition of study participants within a GN (e.g., proportion of female respondents, average household size, etc.). Their inclusion in the model helped to ensure that food environment-diet diversity associations were not confounded by differences in GN composition.

Exploratory analysis was first carried out for the dietary diversity variable to examine the extent of between-GN variance in mean dietary diversity scores, versus within-GN variance, using GN mean-centered dietary diversity scores. The distributions of explanatory variables were also examined and in the case of household total expenditure, which was positively skewed, a logarithmic transformation was performed for inclusion in the multilevel model. Three extreme outliers in the agricultural land holding size variable were also excluded. Bivariate regressions and lowess plots between each explanatory variable, including the food environment exposures, and dietary diversity were carried out to assess linearity of relationships.

Several multilevel Poisson regressions were examined, building to the final model specification in the following order: 1) a random intercept only model; 2) a model adding GN-level variables, including food availability, CoRD, and district membership; 3) a model adding socio-demographic compositional variables; and 4) the final model, adding socio-economic, food security, and agriculture compositional variables. With each model, the random intercept variance was examined to see how much the added covariates reduced GN level variance in DDS. All regressions included only the study participants with complete information for all variables included in the model and GNs with 5 study participants or fewer were excluded.

The multilevel equation for the final model, including compositional variables was as follows:

$$\begin{aligned}\text{Log}(\text{DDS}_{ij}) = {} & \beta_0 + b_{0i} + \beta_1 \mathit{Food\ availability}_i + \beta_2 \mathit{CoRD}_i + \beta_3 \mathit{District}_i + \beta_4 \overline{\mathit{Age}_{i.}} + \beta_5 \overline{\mathit{Sex}_{i.}} + \beta_6 \overline{\mathit{Education}_{i.}} \\ & + B_7 \overline{\mathit{Household\ size}_{i.}} + \beta_8 \overline{\mathit{Log}(\mathit{Expenditure}_{i.})} + \beta_9 \overline{\mathit{Socioeconomic\ status}_{i.}} + \\ & B_{10} \overline{\mathit{Food\ security}_{i.}} + \beta_{11} \overline{\mathit{Agricultural\ land\ holding\ size}_{i.}} + \varepsilon_{ij} \\ & b_{0i} \sim N(0,\tau^2),\ \varepsilon_{ij} \sim N(0,\sigma^2),\ \mathit{corr}(b_{0i}, \varepsilon_{ij}) = 0\end{aligned}$$

In this model, DDS_{ij} is the dietary diversity score of study participant j, $j = 1, \ldots, n_i$ from GN i, $i = 1, \ldots, 45$. β_0 represents the grand mean DDS and b_{0i} is the random intercept for GN_i . ε_{ij} represents the difference between the DDS for study participant i and the mean DDS for GN j. τ^2 is the GN random intercept variance in DDS and σ^2 is the within-GN variance in study participant DDS.

β_1 through β_3 assess the association between DDS and the GN-level (level 2) variables, β_4 through β_7 assess the association between DDS and the socio-demographic composition variables, and β_8 through β_{11} assess the association between DDS and socio-economic, food security, and agriculture composition covariates. Poisson regression allows coefficients to be interpreted as semi-elasticities, therefore beta coefficients are the percentage change in DDS for a unit increase in the explanatory variable (as long as percentages are small).

Lastly, an additional Poisson regression model was run, adding GN-centered study participant (level 1) variables. These variables do not affect the validity of the associations between food environment exposures and dietary diversity, which are the key hypotheses being tested in this study, as group-centered level 1 covariates are independent of level 2 associations with the outcome. However, their inclusion in the model allowed further exploration of the relative importance of individual and household-level factors in explaining dietary diversity versus that of food environment exposures.

Results

Dietary diversity scores were collected for 1,267 study participants and there was an average of 28 participants per GN Division across the 45 study GNs. Summary statistics for individual, household, and GN-level variables are presented in **Table 6.1.** The mean dietary diversity score was 4.73 (out of a total possible of 10). While this study only includes dietary diversity as a simple count, using the MDD-W threshold of five food groups or greater to signify adequate diversity, 55.8% of the study population was likely to have achieved micronutrient adequacy. **Figure 6.1** displays the percentage of study participants who reported consumption of each of the ten food groups included in the DDS. All study participants consumed starches and over 50% consumed other vegetables, meat (including fish), pulses, and other fruit.

A greater percentage of the sample was male (61%) and the average age was 45 years. The average years of education was slightly less than 9 years, indicating having completed grade eight. In Sri Lanka, nine years of education are compulsory and during the tenth year, students begin preparing for national qualifying examinations; 28% of the sample took at least the ordinary qualifying exam (G.C.E. O/L). The average household size was 4.2 members, which is slightly larger than the national average of 3.8 members.

Total household expenditure per person was LKR 646 per person per day ($10.95 in 2011 purchasing power parity (PPP)$). On average, food accounted for 76% of these expenditures. Twenty-six percent of the sample was classified as moderately or severely food insecure. The average size of agricultural land holdings was 1.25 hectares. The SES index was constructed based only on data from study participants, therefore there was roughly an equal number of study participants in each SES quintile.

The mean CoRD was LKR 154.05 per person per day ($2.61 in 2011 PPP$), with an interquartile range of LKR 145.27 – LKR 162.46. This was based on only 38 of the 45 study GNs because 7 GNs were unable to supply the FBDG required variety of items for each food group. It is also the mean CoRD across the three months of the baseline, weighted by the number of participants surveyed in each month. As discussed in *Chapter 1*, CoRD values were on average low relative to household food expenditure (which in this sample of study participants was LKR 468 per person per day). However, variation in CoRD—and its relative affordability—could still be of importance for dietary diversity. The mean GN food availability was 74 items, meaning that less half of the food items included in the pre-defined food list were available during December 2020 – February 2021 in the study area.

Table 6.1 also describes the composition of study participants within the GNs. These GN mean values closely match the grand means reported in the top half of the table. It is evident that variation in study participant composition across GNs exists, but much smaller than the individual-level variance. There were differences in the distributions of study participants and study GNs across the five districts included in the study. While Monaragala contained only 4 study GNs (around 9% of the total number of GNs), it had nearly 25% of the study population, indicating a higher density of study participants in Monaragala GNs as compared to Mannar, for example, which contained 22% of study GNs but only 14% of the study population.

As shown in **Figure 6.2**, there was little evidence of clustering of DDS by GN, though DDS scores did appear to be lower the Batticaloa district (GN identifiers 1 – 15). Low variance in GN mean DDS was also evident in the summary statistics, based on the interquartile range of 4.38 – 5.10, and could reduce the likelihood of detecting significant associations between DDS and GN-level exposures, such as food availability and CoRD.

Figure 6.3 compares the between-GN and within-GN variance in DDS. As mentioned, the interquartile range in the GN average DDS was slightly over 0.5 points, while that of the GN-centered individual DDS was approximately 2 (i.e., a difference of two food groups). The maximum and minimum DDS within GNs were also further apart than the maximum and minimum GN-mean DDS, as shown by the longer box plot whiskers.

Bivariate analysis was conducted for the food environment exposures and all other individual, household, and GN-level covariates to begin assessing whether they were related to the DDS outcome. **Figure 6.4** displays the coefficient and confidence interval of each explanatory variable, when included in bivariate multilevel Poisson regressions with GN random intercepts. These coefficients represent the change in the log expected DDS for a unit change in the explanatory variable (with units and scaled units indicated in italics).

An increase in food availability of 10 unique food items was associated with a 0.02 change in the log expected DDS, or in percentage terms, a 2.0% increase in the number of food groups consumed. An increase of LKR 10 in CoRD was associated with a 2.4% decrease in the number of food groups consumed. These are significant associations that align with hypothesized directions, but appear small in their magnitude. Using the study population mean DDS of approximately 5 food groups, a 20% increase in DDS would be required for 1 additional food group. The GN composition of study respondents' years of education, total expenditure, food security status, and agricultural land holding size also had significant bivariate associations with DDS. The coefficient for mean agricultural land holding was largest: an increase of one hectare in land holding was associated with an 8.2% increase in DDS, though an additional hectare would almost double the mean agricultural land holding size of the study population.

The coefficients were largest for the inter-district comparisons, again reflecting the lower mean DDS in Batticaloa. For example, Mullaitivu had an expected DDS that was 21.9% higher (i.e., an additional food group) than that of Batticaloa.

Table 6.2 shows the results from the multivariate Poisson models and the random intercept only model. These were estimated with robust variance to account for heteroskedasticity. Once adjusted for the categorical district variable, neither of the food environment exposures reached statistical significance. The coefficient for food availability was also in the opposite of the expected direction, and the magnitude of both food availability and CoRD diminished as additional individual and household compositional variables were added in Models 2 and 3.

As noted previously, Batticaloa had lower GN mean DDS scores compared to the other districts. In the final model (Model 4), Mannar had a 21% (95% CI: 8% - 36%) higher and Mullaitivu had a 27% (95% CI: 10% - 43%) higher expected GN mean DDS than Batticaloa, which were both statistically significant associations. No other inter-district comparisons were significant. In the final model, the only other covariate with a significant association with DDS was log household expenditure; a 1% increase in GN mean expenditure was associated with a 0.24% (95% CI: 0.16% - 0.33%) higher expected GN mean DDS. However, to achieve a 20% increase in expected DDS, which would increase an expected mean DDS of 5 (the population mean) by one food group, mean GN household expenditure would need to more than double.

The variance in GN random intercepts disappeared quickly once GN-level covariates were added in Model 1. This was likely due to the lack of significant between-GN variance in DDS that was articulated during the exploratory analysis and shown in **Figures 6.3** and **6.4.** Adding even a small number of GN-level and compositional covariates effectively explained all of the between-GN variance away, with the remaining variance in DDS existing among study participants within GNs. To explore this further, an additional model was run, using GN-centered individual and household covariates.

Table 6.4 displays the results of a multilevel model including the same variables as Model 4, but now, individual and household-covariates are specified both as level 2 composition variables (i.e. GN mean) as well as level 1, study participant-level variables centered around the GN mean, to measure within-GN associations with DDS. In this model, several covariates that had not attained significance as GN composition variables in Model 4 were significant as GN-centered variables. Within a GN, study participants whose years of education differed by a year had a difference in expected DDS of 1.2% (95% CI: 0.7% - 1.7%), survey respondents from households differing by one household member had a difference in expected DDS of 1.3% (95% CI: 0.4% - 2.3%), and survey respondents from households that differ by one socioeconomic status quintile had a difference in expected DDS of 1.9% (95% CI: 0.3% - 3.6%). Total household expenditure also had a significant within-GN association with DDS; survey respondents that differed by 10% in expenditure had a difference of 0.8% (95% CI: 0.5% - 1.0%) in number of food groups consumed.

There was a significant contextual effect (i.e., the between-GN effect minus the within-GN effect) in the association of household expenditure with DDS: two study participants with the same level of household expenditure but residing in GNs that differ by 10% in their mean household expenditure had a difference in expected DDS of 1.7% (95% CI: 0.9% - 2.5%). This means that study participants at any given household expenditure level will experience additional benefit in their dietary diversity by residing in communities that have a higher average expenditure level.

Discussion

Dietary diversity is a proxy for nutrient adequacy, an important dimension of diet quality that may contribute both to ending undernutrition and diet related NCD risks. It is therefore especially critical for LMICs facing the double burden of malnutrition; efforts to improve dietary diversity are central to 'double-duty' actions, in the form of programs and policy that address these interconnected burdens of malnutrition simultaenously[45]. However, constraints to healthy food access in local food environments may curtail progress from such efforts. This study in rural Sri Lanka tested associations between DDS among smallholder farmers and two key food environment characteristics—food availability and diet cost—and found that they were not significantly associated.

Several factors may have contributed to this finding. First, there was not a substantial amount of variation in mean DDS across GNs, the food environment-scale at which the study's availability and cost exposures were measured. The mean DDS in the study population was approximately 5 food groups consumed (out of a total possible ten) and while the interquartile range of DDS across study participants was two food groups (4 – 6), across GNs, the interquartile range for mean GN DDS was just over half a food group (4.38 – 5.10), leaving little variation for food environment exposures to explain. Second, there may not have been meaningful variation in the food environment exposures across GNs. CoRD ranged from a minimum of LKR 125.70 per person per day to a maximum of LKR 197.81 per person per day; however, even this maximum value was a very small percentage of food expenditures reported in the household survey, which had a mean of LKR 469.10 per person per day. GN food availability ranged from a minimum of 46 items to a maximum of 136 items; however, this could reflect greater depth within individual food groups, which may not be as important for food group dietary diversity as having at least a minimum representation of each group in the market.

This study was not designed to survey a variety of food environments – the setting was rather determined by the goals of the R5N impact evaluation and the targeting of WFP's R5N program, which was implemented in communities that were all rural lowland areas, located in the agro-ecological dry zone, vulnerable to food insecurity and climate shocks. Additionally, though spread over five districts, within each district, the study area was within a geographically compact area (one DS Division). Therefore, food environments may have also been relatively similar, or not different enough to have an association with mean DDS in the areas.

One study from rural Ethiopia sought to answer similar questions regarding possible associations between women's dietary diversity and a market food diversity indicator, which measured food group availability in nearby markets. No association was found, except for when the market food diversity indicator was associated with specific agro-ecological zones, where for women in the highland area, who had the lowest overall dietary diversity, market food diversity was positively associated with dietary diversity[42]. Had this study included multiple agro-ecological areas of Sri Lanka—for example highland areas which use different farming systems—especially where dietary diversity varied substantially, similar questions would have been worth exploring. Interaction terms for district and the two food environment exposures considered in this study—food item variety and CoRD—were not significant.

The lack of association between GN-level CoRD and DDS echoes a common finding from high-income countries, where food prices from store audits have not been found to be associated with fruit and vegetable intake[9]. In LMIC studies, while food costs and affordability have been included in a number of studies characterizing food environments, they have not been included in many studies testing associations with diet or nutrition outcomes, which have focused primarily on food availability and physical accessibility to different types of food outlets[8].

In multi-level studies attempting to explore the socio-ecological processes that shape community-level food environment exposures and diet outcomes, where clustering of diet outcomes is not present across communities but substantial variation in outcomes is present within communities, food environment exposures measured at the individual-level may be more likely to produce significant results. Although CoRD only varies at the GN level in this study, an individual food environment exposure could assess food affordability, as CoRD divided by household per capita food expenditure. This was tested by replacing the household expenditure variable in Model 5 with the affordability indicator defined as such; a significant association was found, where, within a GN, an additional 1% increase in CoRD as a share of food expenditure was resulted in a 12% decrease in expected DDS. However, rather than assessing the relationship between the external food environment and diet outcomes, which was the goal of the study, this variable rather captures the effect of household income on increasing purchasing power.

Significant within-GN and between-GN associations were found for household expenditure, which in this study was a proxy for income. Interestingly, a contextual effect of expenditure was also noted. This could indicate that households from the same GN are more similar than households that have the same level of expenditure, but are from different GNs. However, the contextual effect of expenditure could be capturing other GN-level characteristics that were unmeasured in the study, including other food environment related exposures. While food availability and diet costs are important characteristics, food environments are complex and multi-dimensional – their quality may also be determined by other vendor types (e.g. mobile vendors) and vendor properties (e.g. location in relation to households), product properties (e.g. quality or safety), or marketing practices.

Despite some of the limitations discussed here, the study has several strengths. First, it utilized a recently developed cost of diet measure, CoRD, which is now available for a large number of countries and is starting to be incorporated in sub-national analysis[12,46,47]. As the methods for this indicator continue to become more standardized, more comparisons across different settings will be possible[48]. It has also attempted to extend the usage of this indicator, by examining CoRD's associations with diet outcomes at the community-level, for which evidence has been previously unavailable. Lastly, it has used an extensive food list, including many foods that are of local importance in rural Sri Lanka.

Conclusion

Evidence of the food environments influence on diet quality is important for program and policymakers to consider. This study found that in areas of rural Sri Lanka where WFP is delivering a resilience-building food assistance for assets program, food availability and the cost of a healthy diet were not associated with diet diversity in December 2020 - February 2021. This could be a result of the relative homogeneity of the communities included in the study. Future work will further explore these associations while incorporating longitudinal data from monthly follow-ups in traditional markets and retail shops, as well as midline and endline dietary data. Following from the Covid-19 crisis, Sri Lanka has experienced dramatic economic shocks in 2021 related to high levels of debt and a foreign exchange shortage, which have pushed food price inflation to high levels. Therefore, longitudinal effects could be much more detectable than cross-sectional differences among the study population.

Improved surveillance and measurement of food environments using standardized indicators has been strongly advocated by researchers and international organizations alike. However, future work is still needed to determine their appropriateness and informativeness in different contexts. In this study, it is possible that measures utilized—CoRD and a food variety score—were not sufficiently informative to explain dietary diversity in rural areas of Sri Lanka. However, this may not be the case when comparing settings that have greater differences in their diets and food environments—for example, different agro-ecological zones, as well as urban and peri-urban areas. Future research efforts to characterize a more representative sample of Sri Lanka's environmental context and their influence on diet outcomes may be very useful.

Figure 6.1. Percentage of R5N study participants (n=1,270) consuming from food groups included in the dietary diversity score (DDS), December 2020 – February 2021

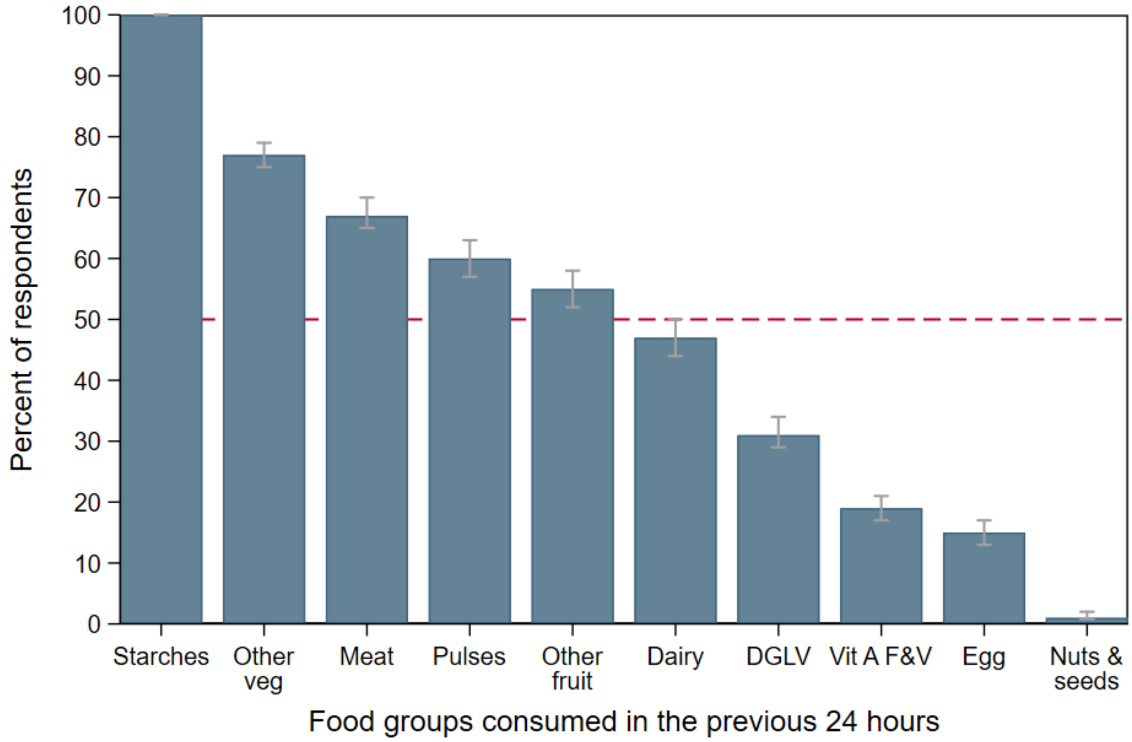


Figure 6.2. Distribution of dietary diversity scores (DDS), grouped by Grama Niladhari Division (GN), across 45 GNs, December 2020 – February 2021

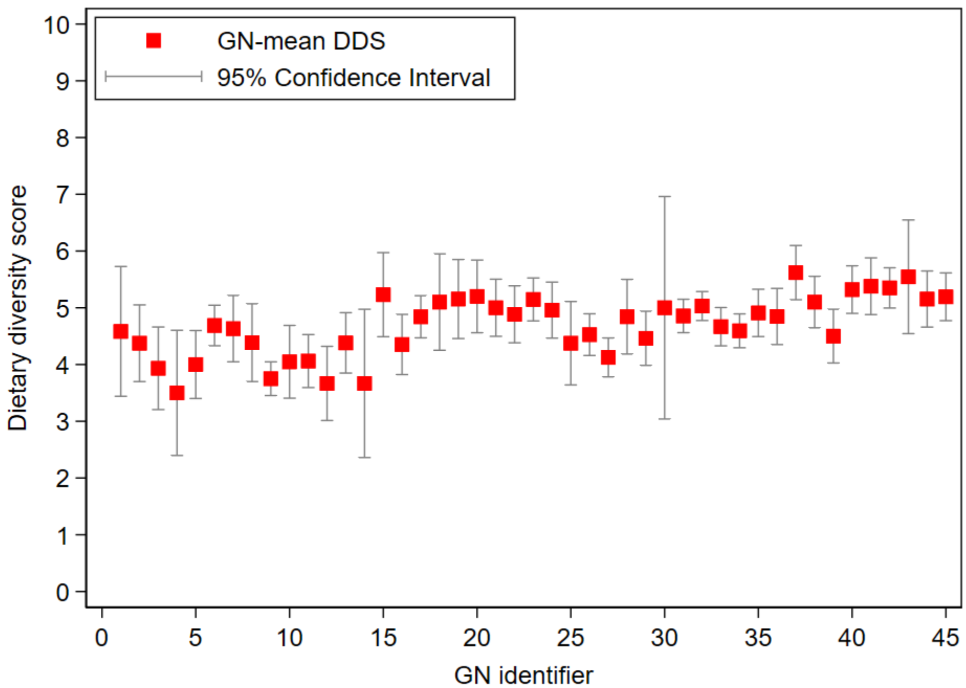


Figure 6.3. Between-GN and within-GN variance in dietary diversity score (DDS) among 1,267 study participants in 45 Grama Niladhari Divisions (GNs), December 2020 February 2021

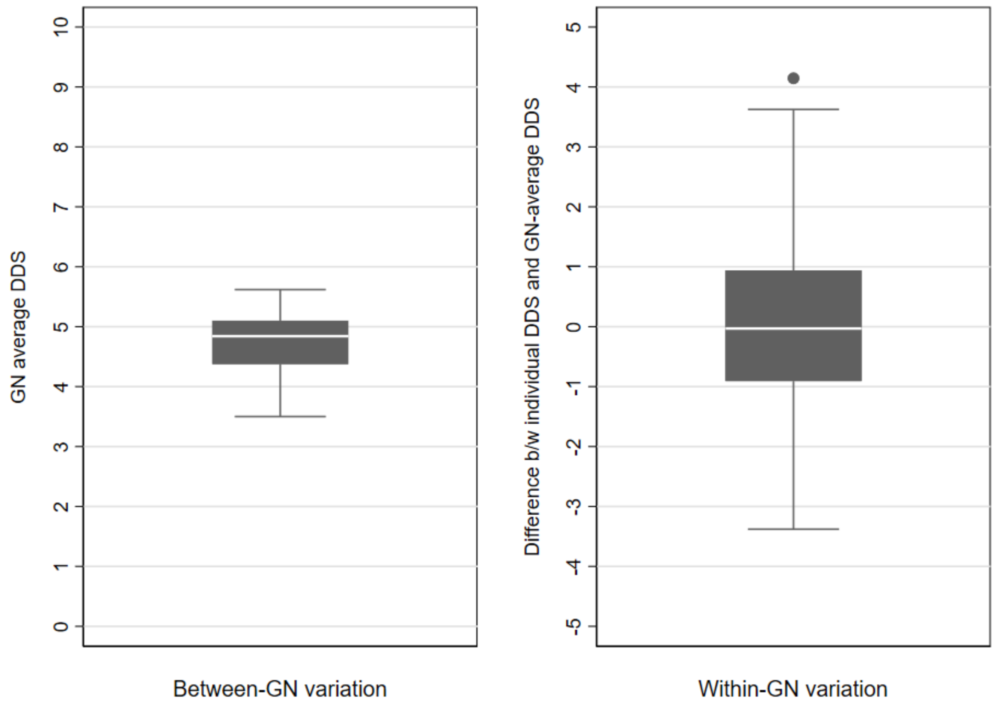


Figure 6.4. Associations from bivariate, multilevel Poisson regression of Grama Niladhari Division (GN)-, household-, and individual-level covariates on dietary diversity scores (DDS) among 1,267 study participants in 45 GNs, December 2020 – February 2021

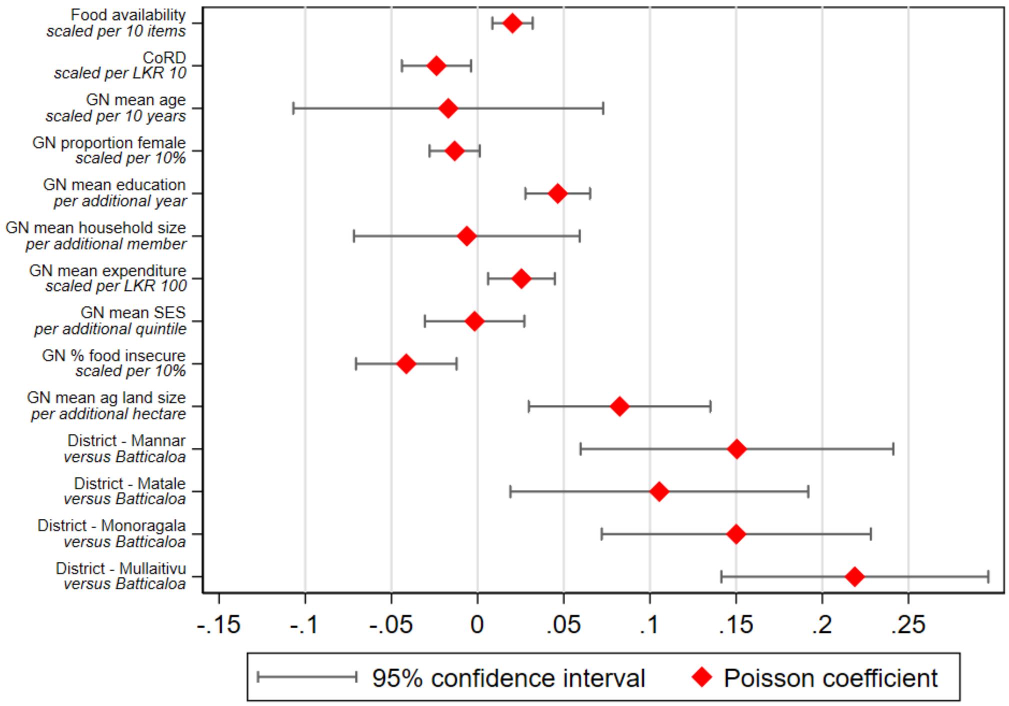


Table 6.1. Individual, household and Grama Niladari Division (GN) summary statistics

Individual & household level variables	**N**	**Mean**	**SD**	**Q1**	**Q3**
Dietary diversity score (DDS)	1267	4.73	1.36	4.00	6.00
Age	1255	45.13	12.64	35.00	54.00
Sex					
Male (%)	770	61.35	-	-	-
Female (%)	485	38.65	-	-	-
Years of education completed	1253	8.79	3.57	6.00	12.00
Household size	1266	4.22	1.56	3.00	5.00
Socio-economic quintile					
First (poorest, %)	239	19.29	-	-	-
Second (%)	247	19.94	-	-	-
Third (%)	244	19.69	-	-	-
Fourth (%)	255	20.58	-	-	-
Fifth (richest, %)	254	20.50	-	-	-
Household expenditure (LKR/person/day)	1245	646.09	502.04	345.26	790.76
Moderate or severe food insecurity (%)	1240	26.21	-	-	-
Agricultural land holding size (hectares)	1136	1.25	1.42	0.40	1.62
District					
Batticaloa (%)	259	20.44	-	-	-
Mannar (%)	171	13.50	-	-	-
Matale (%)	214	16.89	-	-	-
Monaragala (%)	316	24.94	-	-	-
Mullaitivu (%)	307	24.23	-	-	-
GN level variables	**N**	**Mean**	**SD**	**Q1**	**Q3**
Number of respondents per GN	45	28.22	21.38	13.00	38.00
GN average dietary diversity score (DDS)	45	4.69	0.53	4.38	5.10
Food environment exposures:					
Cost of the Recommended Diet (CoRD)	38	154.05	14.53	145.27	162.46
Food availability (total item count)	45	73.78	23.56	54.00	95.00
GN compositional variables:					
GN average age	45	44.81	3.80	42.18	47.58
GN proportion females (%)	45	43.23	25.75	23.44	58.33
GN avg education completed	45	8.49	1.68	7.92	9.55
GN average SES quintile	45	2.65	1.04	1.89	3.62
GN avg household expenditure	45	647.40	151.76	562.10	756.87
GN proportion of food insecurity (%)	45	25.91	13.30	19.05	31.82
GN average land holding size	45	1.22	0.54	0.90	1.48
District					
Batticaloa (%)	12	26.67	-	-	-
Mannar (%)	10	22.22	-	-	-
Matale (%)	8	17.78	-	-	-
Monaragala (%)	4	8.89	-	-	-
Mullaitivu (%)	11	24.44	-	-	-

Table 6.2. Associations from multivariate, multilevel Poisson regression models of Grama Niladhari Division (GN), household, and individual-level covariates on dietary diversity scores (DDS) among 1,185 study participants in 38 GNs, December 2020 February 2021

	Model 1 Random intercept only		**Model 2** With socio-demographic covariates (adjusting for district)		**Model 3** With socio-economic, food security, agriculture covariates (adjusting for district)		**Model 4** With food environment exposures (adjusting for district)	
	Coeff.	*Robust Std. Error*	*Coeff.*	*Robust Std. Error*	*Coeff.*	*Robust Std. Error*	*Coeff.*	*Robust Std. Error*
GN-level variables:								
Food availability (per 10 items)	-	-	-0.009	0.010	-0.009	0.012	-0.003	0.009
CoRD (per LKR 10)	-	-	-0.006	0.010	-0.005	0.011	-0.003	0.012
District:								
Batticaloa	-	-	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
Mannar	-	-	0.158**	0.039	0.153*	0.071	0.217**	0.072
Matale	-	-	0.121*	0.048	0.123	0.078	0.127	0.100
Monaragla	-	-	0.200**	0.051	0.198	0.109	0.162	0.103
Mullaitivu	-	-	0.259**	0.060	0.259*	0.106	0.268**	0.084
Individual and household variables (GN composition):								
GN mean age (per 10 years)	-	-	-	-	-0.014	0.030	-0.038	0.031
GN proportion female (per 10%)	-	-	-	-	-0.005	0.005	0.006	0.007
GN mean years of education completed	-	-	-	-	-0.001	0.018	-0.017	0.016
GN mean household size	-	-	-	-	0.001	0.034	0.032	0.027
GN mean log household expenditure	-	-	-	-	-	-	0.245**	0.045
GN mean socioeconomic status quintile	-	-	-	-	-	-	0.061	0.041
GN proportion food insecure (per 10%)	-	-	-	-	-	-	-0.009	0.011
GN mean agricultural land holding size	-	-	-	-	-	-	-0.012	0.024
Random intercept variance		0.003		0.000		0.000		0.000
Degrees of freedom		2		7		11		15
Akaike's Information Criteria (AIC)		4492		4473		4481		4482

* Significant at $p < 0.05$
** Significant at $p < 0.01$
*** Significant at $p < 0.001$

Table 6.3. Associations from multivariate, multilevel Poisson regression models of Grama Niladhari Division (GN), household, and individual-level covariates (compositional and GN-centered) on dietary diversity scores (DDS) among 1,185 study participants in 38 GNs, December 2020 - February 2021

	Model 5 With individual and household GN-centered covariates	
	Coeff.	*Robust Std. Error*
GN-level variables:		
Food availability	-0.011	0.009
CoRD	-0.011	0.010
District:		
Batticaloa	*Ref*	*Ref*
Mannar	0.292***	0.071
Matale	0.145	0.105
Monaragla	0.226	0.107
Mullaitivu	0.334***	0.086
Individual and household variables (GN composition):		
GN mean age	-0.031	0.031
GN proportion female	0.010	0.007
GN mean years of education completed	-0.036*	0.016
GN mean household size	0.002	0.028
GN mean log household expenditure	0.251***	0.041
GN mean socioeconomic status quintile	0.071	0.044
GN proportion moderately food insecure	-0.008	0.012
GN mean agricultural land holding size	0.000	0.024
Individual and household variables (GN-centered):		
Age	-0.007	0.006
Sex (female vs. male)	0.016	0.017
Years of education completed	0.012***	0.003
Household size	0.014**	0.005
Log household expenditure	0.081***	0.013
Socioeconomic status quintile	0.020*	0.008
Moderately food insecure (vs. not food insecure)	0.004	0.017
Agricultural land holding size	-0.006	0.005
Random intercept variance		0.000
Degrees of freedom		23
Akaike's Information Criteria (AIC)		3974

* Significant at $p < 0.05$
** Significant at $p < 0.01$
*** Significant at $p < 0.001$

References

1. Murray, C. J. L. *et al.* Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 396, 1223–1249 (2020).

2. GBD 2017 Diet Collaborators. Health effects of dietary risks in 195 countries, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* (2019) doi:10.1016/S0140-6736(19)30041-8.

3. Popkin, B. M., Corvalan, C. & Grummer-Strawn, L. M. Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet* vol. 395 65–74 (2020).

4. Foote, J. A., Murphy, S. P., Wilkens, L. R., Basiotis, P. P. & Carlson, A. Dietary variety increases the probability of nutrient adequacy among adults. *J. Nutr.* 134, 1779–1785 (2004).

5. Arimond, M. *et al.* Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. *J. Nutr.* 140, 2059S–69S (2010).

6. Herforth, A. *et al.* A Global Review of Food-Based Dietary Guidelines. *Adv. Nutr.* (2019) doi:10.1093/advances/nmy130.

7. Turner, C. *et al.* Concepts and critical perspectives for food environment research: A global framework with implications for action in low- and middle-income countries. *Global Food Security* 18, 93–101 (2018).

8. Turner, C. *et al.* Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. *Adv. Nutr.* (2019) doi:10.1093/advances/nmz031.

9. Caspi, C. E., Sorensen, G., Subramanian, S. V. & Kawachi, I. The local food environment and diet: a systematic review. *Health Place* 18, 1172–1187 (2012).

10. Masters, W. A. *et al.* Measuring the Affordability of Nutritious Diets in Africa: Price Indexes for Diet Diversity and the Cost of Nutrient Adequacy. *Am. J. Agric. Econ.* 100, 1285–1301 (2018).

11. Herforth, A. & Masters, W. A. *Indicators and Tools for the Cost of Nutritious Diets*. https://sites.tufts.edu/candasa/ (2019).

12. FAO, IFAD, UNICEF, WFP, and WFP. *The State of Food Security and Nutrition in the World 2020: Transforming food systems for affordable healthy diets*. (2020).

13. Chastre, C., Duffield, A., Kindness, H., Lejeune, S. & Taylor, A. *The Minimum Cost of a Healthy Diet - Findings from piloting a new methodology in four study locations*. (2007).

14. Dizon, F., Herforth, A. & Wang, Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security* 21, 38–51 (2019).

15. Bai, Y., Alemu, R., Block, S. A., Headey, D. & Masters, W. A. Cost and affordability of nutritious diets at retail prices: Evidence from 177 countries. *Food Policy* 99, 101983 (2021).

16. Miller, V. *et al.* Availability, affordability, and consumption of fruits and vegetables in 18 countries across income levels: findings from the Prospective Urban Rural Epidemiology (PURE) study. *The Lancet. Global health* 4, e695-703 (2016).

17. Dowler, E. Budgeting for food on a low income in the UK: The case of lone-parent families. *Food Policy* 22, 405–417 (1997).

18. Wiig, K. & Smith, C. The art of grocery shopping on a food stamp budget: Factors influencing the food choices of low-income women as they try to make ends meet. *Public Health Nutr.* 12, 1726–1734 (2009).

19. Dachner, N., Ricciuto, L. & Sciences, N. Food purchasing and food insecurity among low-income families in Toronto. *Can. J. Diet. Pract. Res.* 71, e50-6 (2010).

20. Jayatissa, R., Gunathilaka, M. M. & Fernando, D. N. *Sri Lanka National Nutrition and Micronutrient Survey 2012*. (2012).

21. World Health Organization. Prevalence of anaemia in women of reproductive age. *Global Health Observatory* (2016).

22. NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: A pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* 387, 1377–1396 (2016).

23. Jayawardena, R., Byrne, N. M., Soares, M. J., Katulanda, P. & Hills, A. P. Food consumption of Sri Lankan adults: an appraisal of serving characteristics. *Public Health Nutr.* 16, 1–6 (2012).

24. World Health Organization. *Non Communicable Disease Risk Factors: STEPS Fact Sheet Sri Lanka 2015*. https://www.who.int/ncds/surveillance/steps/STEPS-2015-Fact-Sheet-Sri-Lanka.pdf (2015).

25. Weerasekara, P. C., Withanachchi, C. R., Ginigaddara, G. A. S. & Ploeger, A. Understanding Dietary Diversity, Dietary Practices and Changes in Food Patterns in Marginalised Societies in Sri Lanka. *Foods* 9, (2020).

26. FAO. *The State of Food and Agriculture 2014: Innovation in Family Farming*. https://www.fao.org/3/i4040e/i4040e.pdf (2014).

27. Eckstein, D., Hutfils, M.-L. & Winges, M. *Global Climate Risk Index 2019*. (2018).

28. Brinkman, H.-J., de Pee, S., Sanogo, I., Subran, L. & Bloem, M. W. High Food Prices and the Global Financial Crisis Have Reduced Access to Nutritious Food and Worsened Nutritional Status and Health. *J. Nutr.* 140, 153S-161S (2010).

29. Ruel, M. T., Alderman, H. & Maternal and Child Nutrition Study Group. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *Lancet* 382, 536–551 (2013).

30. Ruel, M. T., Quisumbing, A. R. & Balagamwala, M. Nutrition-sensitive agriculture: What have we learned so far? *Global Food Security* 17, 128–153 (2018).

31. Sibhatu, K. T. & Qaim, M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 77, 1–18 (2018).

32. Gustafson, A., Hankins, S. & Jilcott, S. Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. *J. Community Health* 37, 897–911 (2012).

33. Dizon, F. & Herforth, A. *The Cost of Nutritious Food in South Asia. Policy Research Working Paper 8557*. http://www.worldbank.org/research. (2018).

34. Wfp. *Fill the Nutrient Gap Sri Lanka - Summary Report*. (2018).

35. WFP and HARTI. *Sri Lanka Food Security Atlas: Livelihoods, Food Security, and Resilience*. (2015).

36. Department of Census and Statistics. *Poverty indicators - 2019*. http://www.statistics.gov.lk/Poverty/StaticalInformation/PovertyIndicators-2019 (2022).

37. World Health Organization. *Childhood malnutrition in Sri Lanka: A road map for the last mile*. (2020).

38. Department of Census and Statistics. *Household Income and Expenditure Survey, 2016*. (2018).

39. FAO. *Minimum dietary diversity for women: An updated guide to measurement - from collection to action*. https://doi.org/10.4060/cb3434en (2021) doi:10.4060/cb3434en.

40. Ahmed, S. *et al.* Suitability of Data-Collection Methods, Tools, and Metrics for Evaluating Market Food Environments in Low- and Middle-Income Countries. *Foods* 10, 2728 (2021).

41. Gaillard, C. *et al.* Farm production diversity and women's dietary diversity: Evidence from central Tunisia. *PLoS One* 17, e0263276 (2022).

42. Ambikapathi, R. *et al.* Market food diversity mitigates the effect of environment on women's dietary diversity in the Agriculture to Nutrition (ATONU) study, Ethiopia. *Public Health Nutr.* 22, 2110–2119 (2019).

43. Jayatillake, P. J. & Mahalianaarachchi, R. P. Behavioral pattern of fruit & vegetable consumers in the 'Pola' (Fair) system in Monaragala district in Sri Lanka. *Jiangsu nong ye xue bao* 3, 33 (2007).

44. Liyanage, N. V. R. Behind the curtains of pola: Creating and negotiating local markets in Sri Lanka. (Ball State University, 2016).

45. Hawkes, C., Ruel, M. T., Salm, L., Sinclair, B. & Branca, F. Double-duty actions: seizing programme and policy opportunities to address malnutrition in all its forms. *The Lancet* vol. 395 142–155 (2020).

46. Mahrt, K., Mather, D. L., Herforth, A. & Headey, D. *Household dietary patterns and the cost of a nutritious diet in Myanmar*. http://dx.doi.org/10.2499/p15738coll2.133344 (2019) doi:10.2499/p15738coll2.133344.

47. Raghunathan, K., Headey, D. D. & Herforth, A. *Affordability of nutritious diets in rural India*. http://dx.doi.org/10.2499/p15738coll2.133638 (2020) doi:10.2499/p15738coll2.133638.

48. FAO, IFAD, UNICEF, WFP and WHO. *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable*. http://dx.doi.org/10.4060/cc0639en (2022) doi:10.4060/cc0639en.

Chapter 7. Conclusion

Diet is a leading risk factor in the global burden of disease, accounting for nearly 8 million deaths and 188 million disability-adjusted life-years among adults aged 25 or older in 2019[1]. In LMICs in particular, inadequate and imbalanced diets contribute both to undernutrition—including stunting, wasting, and micronutrient deficiencies—as well as a growing burden of non-communicable diseases (NCDs)[2]. Changes in local food environments may contribute to the nutrition transition that many LMICs are undergoing, however, food environment research is still in its infancy in these settings[3].

Smallholder farmers in LMICs are among the world's most vulnerable to food insecurity and inadequate diets, and have been the focus of nutrition-sensitive agriculture interventions, which aim enhance agriculture's contributions to nutrition[4,5]. One key pathway through which these improvements could be achieved are by enhancing the production of nutritious foods. Systematic reviews, however, have indicated weak contributions of household food production diversity to diversifying the diets of smallholders[6,7]. In most contexts, access to markets have been much more powerful contributors to the dietary diversity of smallholders. Yet, little is known about amount the quality of food environments in markets where smallholders acquire food, as the majority of food environment research in LMICs has taken place in urban areas.

This study characterized the food environment in terms of food availability and food costs, and assessed their influence on diet quality among adults from farming households in 45 GN Divisions, across five rural districts of Sri Lanka. Over the past two decades, as prevalence of overweight (BMI >= 25 kg/m^2) has increased from 14% to 24% among adults in Sri Lanka, high prevalence of anemia and acute malnutrition among pregnant women have persisted, mirroring the trend towards the double burden of malnutrition that is now common in LMICs[2,8,9]. Sri Lanka has experienced economic growth during this time, but income inequality is among the highest in the region[10]. Low-income households are especially vulnerable to rising food prices, which have been a national concern for diet quality, also due to their seasonal variation and short-term fluctuations[11]. During the study period, from December 2020 to December 2021, Sri Lanka's food system experienced shocks related to Covid-19 and a foreign exchange crisis, caused by decreases in export and tourism revenues and the demands of its large outstanding debt, which were manifest in high food price inflation and reports of food scarcity[12].

This food environment research was conducted as a sub-study within the R5N impact evaluation, led by the IFPRI, which is evaluating the impacts of a WFP food assistance for assets intervention, known as the R5N program, on diet and income outcomes among smallholder farming families vulnerable to climate shocks. Evidence from this sub-study was intended to shed light on the food environment context in which the R5N program is implemented, which may affect the adequacy of the program to produce the intended income and diet outcomes, while also furthering knowledge of food environment-diet linkages in rural Sri Lanka, where such evidence is limited.

Summary of findings

Characterizing the food environment in 45 rural Grama Niladhari Divisions of Sri Lanka

In December 2020, food environments in the R5N study area could be characterized as offering food that was sufficiently available and affordable for households to attain healthy diets. With few exceptions, GN-level food environments, comprised of local retail shops and the two nearest traditional markets, offered a diversity of food groups, with additional depth within groups where variety is encouraged, such as fruits and vegetables. The cost of a healthy diet, measured as CoRD, LKR 155.39 ($2.63 2011 PPP$) per person per day, represented 48% of average household food expenditure and just 15% of the households included in the R5N impact evaluation study appeared to have insufficient income to afford that diet. Even a more expensive diet that meets FBDG while reflecting consumer preferences, CoRD-FP was affordable to 40% of the households surveyed.

The preference premium associated with protein foods, measured as the ratio of the protein component in CoRD-FP divided by the protein component of CoRD, was large (4.95) relative to other food groups, reflecting the significant difference between the low-cost protein-rich items selected in the standard CoRD measure (typically dried sprats or another dried fish and red dhal) versus other preferred protein-rich foods, such as fresh fish, chicken, and eggs, which are all included in the CoRD-FP weighted average. This premium was larger than that estimated in Myanmar using similar methods, which found the cost of protein-rich foods under CoRD-FP to be 3.5 times higher than CoRD, however, protein foods also had the highest premium in that study[13].

There was geographic variation in mean CoRD across the five districts. Matale had the cheapest CoRD, at LKR 145.28 per person per day, while Monaragala's was the most expensive, at LKR 179.95 per person per day. However, the affordability of CoRD was also the highest in both of these districts, at 57% of household food expenditure, because Matale also had a substantially lower food expenditure on average than the other districts.

While spreading market purchases over multiple markets and retail shops would not be necessary for residents to physically access sufficient variety of foods for FBDG, this strategy would enable them to achieve cost savings by accessing lower cost foods. For example, in the protein group, not all outlets surveyed had the cheaper items mentioned above—dried fish or red dhal—so combining retail shops and markets in food sourcing strategies, or traveling to a slightly further away market, may enable consumers to substitute more expensive items—such as fresh fish—with those cheaper proteins should they choose to. Similarly, residents in many GNs may need to shop around to identify milk powder, which presented significant cost savings over more expensive dairy items.

Ultra-processed foods were widely available in village retail shops throughout the study area. In contrast, retail shops tend to stock few fresh fruits and vegetables. Given the easier access of retail shops, which are open more frequently and are located closer to households, this could be a concern, especially for communities that are located far from markets. Some ultra-processed foods were also relatively cheap, including instant noodles, which are often consumed as a meal and could risk substituting more nutrient-dense dishes.

Assessing trends in the cost and availability of a healthy diet in rural Sri Lanka during Covid-19

Post-baseline, there were significant decreases in food availability and increases in increases in food costs, which may have restricted vulnerable households' access to a healthy diet. In September 2021, only 62% of the 45 study GNs offered sufficiently diverse foods to meet recommendations in FBDG, and this was as low as 28% under a scenario where households do not spread food purchases over multiple traditional markets. After adjusting for non-food price CPI, the real cost of a healthy diet, measured using CoRD, increased by 25% over the study period, from LKR 155 per person per day in December 2020 to LKR 196 per person per day in December 2021.

Through comparison with national data from Sri Lanka's food price surveillance system, the study also provided some evidence that increases in CoRD may have been more pronounced in remote, rural communities like where the R5N program is implemented relative to urban centers where the national surveillance system collects data. Using an abbreviated measure of CoRD that did not include dairy, the R5N area experienced an increase in diet cost that was nearly triple the national average increase. This can be compared with research on food prices and Covid-19 from India, which found that initial price increases during the pandemic dissipated more rapidly in larger cities relative to smaller cities, perhaps due to more concerted efforts to stabilize supply chains in denser populated areas (Raghunathan presentation). An examination of staple food prices in six African countries also consistently identified higher prices in rural areas as compared to urban areas during Covid-19, which were credited to multiple factors, including increased transport and transaction costs along supply chains as well as the stronger dampening effect of consumer demand in urban areas[14].

Though the study could not evaluate seasonal patterns of CoRD in the R5N area due to the limited time range of the study period and several months when data collection was not possible due to Covid-19 restrictions, analysis of national data indicates that there was an increase in seasonal variation during Covid-19 (March 2020 – December 2021) relative to a historical pattern, based on January 2014 to February 2020 data. This increased cost volatility could relate to lower availability of food during Covid-19, which would offer fewer low-priced substitution options to maintain a low-cost CoRD. However, the typical seasonal effect on CoRD in Sri Lanka appears to be small, especially relative to African contexts where seasonal variation in diet costs have been evaluated[15,16].

The influence of the food environment on diets in rural Sri Lanka: Testing associations between food availability, cost of a recommended diet, and dietary diversity among smallholder farmers

Associations with dietary diversity among smallholder farmers in the R5N area were tested for two food environment exposures: food availability, measured as a count of the unique food items available in a GN, and the cost of a healthy diet, measured as CoRD. In this cross-sectional analysis using only baseline data gathered between December 2020 and February 2021, the associations for both were non-significant.

There was limited variation in mean dietary diversity score (or DDS) across GNs, the food environment-scale at which the study's availability and cost exposures were measured, which could partially explain these null results. The mean DDS in the study population was approximately 5 food groups consumed (out of a total possible ten) and while the interquartile range of DDS across study participants was two food groups (4 – 6), across GNs, the interquartile range for mean DDS was just over half a food group (4.38 – 5.10), leaving little variation for food environment exposures to explain. Second, there may not have been meaningful variation in the food environment exposures across GNs. CoRD ranged from a GN minimum of LKR 126 per person per day to a maximum of LKR 198 per person per day, however, even this maximum value was a very small percentage of food expenditures reported in the household survey, which had a mean of LKR 469 per person per day. GN food availability ranged from a minimum of 46 items to a maximum of 136 items, however, this could reflect greater depth within individual food groups, which may not be as important for food group dietary diversity as minimum representation of each group in the market.

One study from rural Ethiopia sought to answer similar questions regarding possible associations between women's dietary diversity and a market food diversity indicator, which measured food group availability in nearby markets. No association was found, except for when the market food diversity indicator was interacted with agro-ecological zone, where for women in the highland area, who had the lowest overall dietary diversity, market food diversity was positively associated with dietary diversity[17]. In contrast, this study took place within an agro-ecologically homogenous group of communities, since WFP's intervention was designed to address vulnerability to climate shocks among smallholders in Sri Lanka's dry zone. It was further targeted to low-income communities that were vulnerable to food insecurity and malnutrition. This could have limited the variance in food environment measures that the study utilized as well as their associations with diet outcomes, relative to a sample of food environments that may have spanned agro-ecological areas, or even included peri-urban and urban areas.

In contrast to the lack of significant associations between GN-level food environment exposures and dietary diversity, several individual and household-level covariates had significant within-GN associations. These included the study participant's years of education, household size, socio-economic status, and household food expenditure. Interestingly, a contextual effect of household expenditure was also noted, wherein: two study participants with the same level of household expenditure, but residing in GNs that differ by 10% in their mean household expenditure had a difference in expected DDS of 1.7% (95% CI: 0.9% - 2.5%). This could indicate that households from the same GN were more similar than households that had the same level of expenditure, even if they were from different GNs. However, the contextual effect of expenditure could also be capturing other GN-level characteristics that were unmeasured in the study, including other food environment related exposures. While food availability and diet costs are important characteristics, food environments are complex and multi-dimensional – their quality may also be determined by other vendor types (e.g. mobile vendors) and vendor properties (e.g. location in relation to households), product properties (e.g. quality or safety), or marketing practices.

Strengths and Limitations

This study had several limitations. First, due to limited resources and enumerators, it was only possible to collect data from the two food vendor types that were determined to be most important for rural food access based on literature review and key informant reviews, prior to beginning the data collection. This necessitated a simplified definition of the food environments that households engage with, which may not in all cases reflect the food environments they actually engage with. For example, two possibilities not accounted for in this design were: that households purchase a substantial quantity of food from mobile vendors or streetside vendors; or households will travel further away, possibly to larger markets in small cities, to conduct weekly grocery shopping.

Second, it was not possible in the study to adequately characterize the importance of another type of food environment that is critical in rural areas – that of cultivated food environment – where smallholders may procure foods for consumption through their own production[18]. This would have required more systematic information about the full range of crops produced by households, quantities harvested, and quantities sold versus consumed, which was not possible in the shortened version of the household survey that was adapted for phone interviewing. Though previous research has shown this own production – own consumption pathway to produce limited impacts on dietary diversity, interacting variables such as household-level crop diversity would have provided more insight into how smallholder farmers were affected by market food availability and diet costs, and whether household food production is able to protect diets from low availability-high cost environments[7].

Third, due to the rise of Covid-19 cases in Sri Lanka during the Delta wave, it was not possible to collect data during several months, including– May 2021, June 2021, August and 2021. This missingness limited a fuller view of the temporal changes in food environments during the study period, and also prevented comparison with national data from HARTI during those months. Additionally, during months when data collection was possible, it was not always possible to reach all of the sampled traditional markets and retail shops, as some would occasionally close due to localized Covid-19 outbreaks and containment policies. These closures may have also reduced access to food among households living nearby, so food environment estimates produced only from the markets and shops that remained may open (which were often increased costs or lowered availability) may accurately reflect this reduced access; however, it is also possible that households substituted vendors and therefore were not affected by these closures in the way the data would suggest.

Finally, similarities across study sites, which were necessary for WFP's R5N program to be effective and were important in an impact evaluation context, were not necessarily conducive to studying variation in food environments and their association with diet outcomes. Greater variation in food environments and diets may have been found in a sample that also represented different agro-ecological zones of Sri Lanka. Though rural areas in LMICs have been understudied, including communities at different stages along the rural-peri-urban-urban continuum may have also generated informative comparisons regarding food environments.

A key strength of the study was that through close collaboration between study partners, dietary, household, and market surveys were coordinated in a way that enabled evidence-generation related to community-level food environment-diet linkages in a context—rural Sri Lanka—were this was previously unavailable. Conducting community-level food environment research may provide a more accurate view of what food environments look like at the scale at which consumers actually engage with them, while translating national-level food environment information to communities may be subject to ecological fallacies. This is especially the case with food prices, which, while often gathered subnationally, may sample disproportionately from urban centers, missing the types of markets that operate in remote rural areas[19,20]. While cost of diet measures have now become a fixture in the global monitoring of food access, these provide national estimates for indicators like CoRD; studies examining sub-national variation are less common, and at the community-level, merging dietary data from local consumers, rare[21].

A second strength of the study was the embedding of this food environment research as a sub-study within the R5N impact evaluation. This design enabled the study to generate epidemiological evidence through the merging of market, household, and dietary data, as described above, but was also part of an important research-implementation partnership, which aimed to contribute to more evidence-based programs. The sub-study provided contextual information regarding the food environment study participants and program beneficiaries were engaged with, which may also influence the effectiveness of the R5N intervention in improving diet quality.

Implications

This study aimed to characterize food environments in rural areas of Sri Lanka participating in WFP's R5N program, assess changes in those food environments between December 2020 and December 2021, and test associations between food environment exposures and dietary diversity among study participants. This evidence was intended to expand knowledge of how food environments affect diet quality in rural areas of LMICs and also to inform the R5N program and impact evaluation.

In December 2020, it was found that foods that make up a healthy diet, as defined by Sri Lanka's national FBDG, were highly available and highly affordable relative to household food expenditure. This is one reason why it may not come as a surprise that there were not significant associations between food availability and dietary diversity during the R5N study baseline, between December 2020 and February 2021. Baseline evidence regarding the availability and affordability of a healthy diet could bode well for WFP's R5N program, which is building resilience among smallholders through a combination of water infrastructure rehabilitation, training, transfers, and health promotion, which it hopes will improve incomes and diet quality. The lack of apparent external food environment constraints could increase the likelihood that the R5N activities will translate into the desired impacts – e.g. that income generated from improved production will be sufficient to purchase more nutritious food and that availability gaps will not limit the items that can be selected. This possibility is also supported by the significant within-GN association of household expenditure and dietary diversity.

However, more concerning findings from the study related to the temporal changes in availability and cost of a healthy diet in the R5N area, especially as the foreign exchange crisis began to fully emerge during the second half of 2021. After adjusting for inflation there was still real growth in CoRD of 25% during the study period. The most pronounced cost increases took place beginning in September, which was also the month with the greatest availability gaps. This timing was aligned with key turning points in Sri Lanka's foreign exchange crisis, for example, when an economic emergency was declared in August 2021 and when food CPI took a steep turn upwards in September 2021. The contribution of this study to those national developments has been to: a) confirm that the food shortages and price increases reported in news media, typically focused in urban areas such as Colombo, were also felt in remote rural areas of Sri Lanka; and b) to show that the cost of a healthy diet was not resilient to these changes, i.e. substitution effects among different foods within food groups would have been insufficient to maintain a low CoRD in the face of overall food price inflation.

These changes demonstrate that the calls for food environment research to incorporate more longitudinal designs are justified, especially in the presence of shocks like what Sri Lanka has experienced over the previous two years[3]. Food environments are fluid and may change throughout the year, especially in rural areas that are affected by seasonality in food production or systemic shocks to food supply chains that may affect distribution to remote areas. These contextual changes to the food environment may also affect the R5N's program effectiveness. While at baseline, affordability appeared relatively safe, increases in food price later in the year could reduce purchasing power, especially if household income losses are occurring simultaneously, which is plausible given the increased cost of agricultural inputs and reduced productivity that was reported nationally[22]. Future analysis will incorporate this longitudinal food environment data with midline and endline household and diet data to determine whether increases in CoRD over time were associated with reductions in dietary diversity. This analysis will also examine whether participation in one of the treatment arms (R5N or R5N plus health promotion) was protective of cost increases versus the control arm. Continued efforts to analyze diet data are also ongoing, with the intention of describing diet quality across other dimensions besides diversity. Associations between food environment exposures and these other measures, such as quantities of foods (e.g. fruits and vegetables) or overall dietary quality, may also be tested. Given the paucity of previous evidence from large scale dietary surveys in Sri Lanka, the precise nature of diet inadequacies in different parts of the country is still not well described, and it could be the case that these are not captured by a food group-based dietary diversity score.

This work has also shown that there may be additional benefits to studying a more representative sample of food environments in Sri Lanka, including different agro-ecological zones and different urban, peri-urban and rural contexts. Open questions remain regarding the quantity of variation in market food environment characteristics such as those addressed in this study—food availability, food costs, and affordability—that exists at different geographic scales, the appropriateness and precision of the indicators used to capture that variation, and the level of variation that is meaningful for diet outcomes. Comparisons across food environments that differ more substantially may contribute further to answering some of these questions. Lastly, though, the study attempted to describe multiple dimensions of the food environment, additional research is also needed other dimensions not described in the study, which include how foods are marketed and promoted, as well as their quality. These dimensions have received less attention in the development of methods, tools, and metrics[23]. However, they remain important features of food environments and their possible role in food systems and nutrition transitions in LMICs.

References

1. Murray, C. J. L. *et al.* Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet* 396, 1223–1249 (2020).

2. Popkin, B. M., Corvalan, C. & Grummer-Strawn, L. M. Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet* vol. 395 65–74 (2020).

3. Turner, C. *et al.* Food Environment Research in Low- and Middle-Income Countries: A Systematic Scoping Review. *Adv. Nutr.* (2019) doi:10.1093/advances/nmz031.

4. FAO. *The State of Food and Agriculture 2014: Innovation in Family Farming*. https://www.fao.org/3/i4040e/i4040e.pdf (2014).

5. Ruel, M. T., Alderman, H. & Maternal and Child Nutrition Study Group. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? *Lancet* 382, 536–551 (2013).

6. Ruel, M. T., Quisumbing, A. R. & Balagamwala, M. Nutrition-sensitive agriculture: What have we learned so far? *Global Food Security* 17, 128–153 (2018).

7. Sibhatu, K. T. & Qaim, M. Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 77, 1–18 (2018).

8. NCD Risk Factor Collaboration (NCD-RisC). Trends in adult body-mass index in 200 countries from 1975 to 2014: A pooled analysis of 1698 population-based measurement studies with 19.2 million participants. *Lancet* 387, 1377–1396 (2016).

9. Jayatissa, R. *et al. National Nutrition and Micronutrient Survey of Pregnant Women in Sri Lanka 2015*. (2017).

10. World Bank. Poverty and Equity Data: South Asia. *Poverty and Equity Data Portal* (2022).

11. WFP. *Sri Lanka National Strategic Review of Food Security and Nutrition: Toward Zero Hunger*. (2017).

12. Thowfeek, R. Sri Lanka's dilemma: Pay off debt or pay for milk, meds and gas. *Al Jazeera* (2022).

13. Mahrt, K., Mather, D. L., Herforth, A. & Headey, D. *Household dietary patterns and the cost of a nutritious diet in Myanmar*. http://dx.doi.org/10.2499/p15738coll2.133344 (2019) doi:10.2499/p15738coll2.133344.

14. Yade, M. *et al.* The Impact Of COVID-19 On Staple Food Prices: Location Matters. in *2021 Annual Trends and Outlook Report: Building Resilient African Food Systems after COVID-19* (eds. Ulimwengu, J. M., Constas, M. A. & Ubalijoro, É.) 25–45 (Akademiya 2063 and IFPRI, 2021).

15. Bai, Y., Naumova, E. N. & Masters, W. A. Seasonality of diet costs reveals food system performance in East Africa. *Science Advances* 6, (2020).

16. Schneider, K., Christiaensen, L., Webb, P. & Masters, W. A. *Assessing the Affordability of Nutrient-Adequate Diets*. https://openknowledge.worldbank.org/handle/10986/36485 (2021).

17. Ambikapathi, R. *et al.* Market food diversity mitigates the effect of environment on women's dietary diversity in the Agriculture to Nutrition (ATONU) study, Ethiopia. *Public Health Nutr.* 22, 2110–2119 (2019).

18. Downs, S. M., Ahmed, S., Fanzo, J. & Herforth, A. Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets. *Foods* 9, (2020).

19. Gaddis, I. *Prices for Poverty Analysis in Africa*. http://dx.doi.org/10.1596/1813-9450-7652 (2016) doi:10.1596/1813-9450-7652.

20. Dizon, F., Herforth, A. & Wang, Z. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. *Global Food Security* 21, 38–51 (2019).

21. FAO, IFAD, UNICEF, WFP and WHO. *The State of Food Security and Nutrition in the World 2022. Repurposing food and agricultural policies to make healthy diets more affordable*. http://dx.doi.org/10.4060/cc0639en (2022) doi:10.4060/cc0639en.

22. Wipulasena, A. & Mashal, M. Sri Lanka's Plunge Into Organic Farming Brings Disaster. *The New York Times* (2021).

23. Ahmed, S. *et al.* Suitability of Data-Collection Methods, Tools, and Metrics for Evaluating Market Food Environments in Low- and Middle-Income Countries. *Foods* 10, 2728 (2021).

Appendix 1. Survey questionnaires, food list, and training materials

Appendix 1.1. Sampling and data collection guidance for food environment enumerators

Appendix 1.2. Traditional market questionnaire

Appendix 1.3. Village retail shop questionnaire

Appendix 1.4. Survey food list, FBDG, RCP, and NEMS-S groupings

Appendix 1.1. Sampling and data collection guidance for food environment enumerators

GUIDANCE FOR R5N MARKET ENUMERATORS ON HOW TO COLLECT FOOD PRICES IN MARKETS

Which markets to collect data from?

- Enumerators will be notified which markets they should collect data from by Dr. Hemachandra and Sharunya. This is true for village retail shops as well.

When to collect the data?

- Enumerators are asked to gather data from markets during the second week of each month (i.e. from the 8th to the 14th). In some cases, a few more days may be allowed (until the 17th), but you should notify team leaders and Sharunya when this is the case.
- Enumerators visiting pola markets will need to visit those markets during the days when they are operating. Enumerators visiting permanent markets may visit those on any day within the second week of the month.
- Time of the day: Enumerators should try to collect data when the largest number of sellers are present. It is best not to go first thing in the morning when vendors are still arriving, nor at the end of the day, when vendors are starting to leave. Outside of these times, you should use your best judgement. The range of 9:00 am to 11:00 am may be a good time to start but this could depend on the market.

Which vendors to collect data from?

- Enumerators should attempt to find three price observations for each food item, but in many cases, there will be more than three vendors selling a certain item, so you will need to choose which vendors to include in the data collection.
- A good strategy is to first take a walk around the market to get an idea about the area and scan to identify which parts of the market different food groups are concentrated in before beginning the questionnaire.
- Vendors included should be sampled from a variety of locations in the market, including the *front, middle*, and *back* of the market. Try to ensure that all three price observations for a food item **do not** come from the entrance to the market, where prices are typically higher.
- Enumerators may also include vendors of a variety of sizes, including vendors with only a small number of products for sale and others with a larger number of products.
- Note that sampling vendors from locations in the market and of different sizes only needs to apply to the overall sample – it does not need to apply to each individual food item.

Which varieties of food to collect prices for?

- In some cases, several different varieties maybe available for a food item listed in the questionnaire. For example, there may be potatoes that are local or imported, or different varieties of pumpkins. In these cases, enumerators should collect prices for whichever variety is most widely available or most commonly purchased. Market vendors may be able to advise.

Which quality of food to collect prices for?

- Enumerators should try to collect prices for food items that are of *average* quality in the market.
- Enumerators should try to avoid collecting prices for food items that are obviously damaged or close to their expiration date. These food items may be priced lower as a result of poor quality.
- Enumerators should also try to avoid collecting prices for premium (very high) quality food items that are purchased by only a small percentage of wealthier consumers visiting the market. These consumers may not represent the target population the study is interested in.

Appendix 1.2. Traditional market questionnaire

Sri Lanka Food Environment Study – Market Questionnaire

I. Survey information – *To be entered for each round of data collection*

1	Date of survey	|__|
2	Start time of survey	|__|
3	End time of survey	|__|
4	Enumerator name	|__|
5	Market name	|__|
6	GPS coordinates	|__|

II. Market information – *This information should be collected through observation by the enumerator, consulting with vendors and other key informants in the market as necessary. Some items will be removed after the baseline survey.*

7	Type of market	1 = Pola/santhai market (weekly outdoor market) 2 = Permanent outdoor market 3 = City market 4 = Other (Specify ______)	|__|
8	Days of operation *Select all that apply*	1 = Monday 2 = Tuesday 3 = Wednesday 4 = Thursday 5 = Friday 6 = Saturday 7 = Sunday	|__|
9	Normal hours of operation		|__|:|__| - |__|:|__|
10	Number of vendors/stalls	1 = 1 2 = 2 – 5 3 = 6 – 15 4 = 16 – 50 5 = 51 – 100 6 = 101 – 200 7 = 201 – 500 8 = Over 500	|__|

11	Are there fewer than five vendors selling any of the following types of products?		
		Yes	No
11_a	Cereals (e.g. rice)		
11_b	Legumes (e.g. dhal, green gram)		
11_c	Vegetables		
11_d	Fruits		
11_e	Milk and dairy (e.g. yoghurt, curd)		
11_f	Eggs		
11_g	Fish, chicken, lamb, other meat		
12	Does the market have a permanent roof (made of concrete)	1 = Yes 2 = No → *If no, skip to question 14*	|__|
13	Does the permanent roof cover 50% of the market?	1 = Yes 2 = No	|__|
14	What type of covering exists where there is no permanent roof?	1 = No covering/open air 2 = Tarp or canvas 3 = Corrugated iron or wood 4 = Other (Specify___)	|__|
15	Please indicate the availability of the following infrastructure in the market:		
		Yes	No
15_a	Closed sewage system		
15_b	Dedicated waste collection area		
15_c	Access to water via pump or tap (inside the market)		
15_d	Toilets (within a short walk)		
15_e	Electricity		
15_f	Refrigeration for fresh fish and meat		
15_g	Other cold storage for fresh fish and meat		
15_h	Reliable communication network (mobile phone coverage and/or internet)		
15_i	Access to the market via a paved road		
16	Are prepared foods and beverages sold at the market?	1 = Yes 2 = No → *Skip to food list*	|__|
17	Please indicate the types of prepared foods sold in the market: *Select all that apply*	1 = Rice and curry 2 = Kottu roti 3 = Short eats (baked) 4 = Short eats (fried) 5 = Vegetable dishes 6 = Other (specify___)	

III. **Food list –** *Enumerators will attempt to collect three* ***retail*** *price observations for each food item. For foods that are not available, the code 99=not available, should be entered. This code can be used if no observations can be found (i.e. the food item is not sold in the market), or, for example, if only three observations can be found, but not the fourth and fifth. Once the not available code has been used, it will be assumed that subsequent observations are also not available.*

Unit codes: 1 – kilograms, 2 – grams, 3 – liters, 4 – milliliters, 5 – each, 6 – bunch

Item	Price 1 (LKR)	Quantity 1	Unit 1	Price 2 (LKR)	Quantity 2	Unit 2	Price 3 (LKR)	Quantity 3	Unit 3
Ex. Rice	1,000	1	Kg	3,500	4	Kg	800	750	Grams

Appendix 1.3. Village retail shop questionnaire

Sri Lanka Food Environment Study – Retail Shop Questionnaire

IV. Survey information – *To be entered for each round of data collection*

1	Date of survey	|__|
2	Start time of survey	|__|
3	End time of survey	|__|
4	Enumerator name	|__|
5	Retail shop name	|__|
6	GPS coordinates	|__|

V. Retail shop information – *This information should be collected through observation by the enumerator, consulting with the shop owner or manager as necessary. Some items will be removed after the baseline survey.*

7	Type of retail shop	1 = Village retail shop 2 = Vegetable/fruit shop (green grocer) 3 = Grocery store 4 = Other (Specify ________)	|__|
8	Days of operation *Select all that apply*	1 = Monday 2 = Tuesday 3 = Wednesday 4 = Thursday 5 = Friday 6 = Saturday 7 = Sunday	|__|
9	Normal hours of operation		|__|:|__| - |__|:|__|
10	Size of retail shop	1 = Less than 10 square meters 2 = 10-20 square meters 3 = 21-50 square meters 4 = 51-100 square meters) 5 = Greater than 100 square meters	|__|

11	Please indicate the availability of the following infrastructure in the market:		
		Yes	No
11a.	Electricity		
11b.	Refrigeration		
11c.	Other cold storage		
11d.	Reliable communication network (mobile phone coverage and/or internet)		
11e.	Access to the shop via a paved road		

VI. **Food Items –** *In this section of the questionnaire you will be asked to indicate the availability and gather price information for a range of food groups. Please inquire with store vendors about prices when these are not displayed, and as otherwise needed. In the case of packaged foods (e.g. canned products, frozen items) you may also need to check packaging for the unit information (e.g. number of grams in a can, number of liters in bottle, etc.).*

Click "Next" to continue.

Fruits

12	Are fruits available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 14*	|__|
13. If yes, select which fruits are available by entering the price and unit information (using the same list from the market questionnaire fruits list).			

Non-starchy vegetables

14.	Are fresh vegetables available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 16*	|__|
15. If yes, select which vegetables are available by entering the price and unit information (using the same list from the market questionnaire vegetables list, including vegetables (non-starchy) and leafy vegetables).			
16.	Are canned vegetables available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 18*	|__|
17.	Select which canned vegetables are available by entering price and unit information. If multiple brands of the same product are available, please enter the information for the cheapest brand.		
	Item	**Price per can**	**Size of can (grams)**
17a.	Corn		
17b.	Green peas		
17c.	Mushrooms		
17d.	Beans (Baked)		
17e.	Beans (Green)		
17f.	Other (specify:______)		

Roots and tubers (starchy vegetables)

18.	Are roots and tubers (starchy vegetables) available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 20*	|__|
19. If yes, select which roots and tubers are available by entering the price and unit information (using the same list from the market questionnaire root and tuber (starchy vegetables) list.			

Pulses

20.	Are pulses (e.g. dhal, grams) available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 22*	|__|
21. If yes, select which pulses are available by entering the price and unit information (using the same list from the market questionnaire pulse list).			

Grains, flour, bread, pasta and noodles

22.	Are grains available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 24*	|__|	
23. If yes, select which grains are available by entering the price and unit information (using the same list from the market questionnaire grain list).				
24.	Is flour available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 26*	|__|	
25.	Select which types of flour are available is available by entering price and unit information. If multiple brands of the same product are available, please enter the information for the cheapest brand.			
	Item	**Price**	**Quantity**	**Unit**
25a.	White rice flour			Enter unit_code
25b.	Red rice flour			Enter unit_code
25c.	Wheat flour (white)			Enter unit_code
25d.	Whole wheat flour (atta)			Enter unit_code
25e.	Kurakkan flour			Enter unit_code
25f.	Gram flour (chickpea)			Enter unit_code
25g.	Ulundu flour			Enter unit_code
25h.	Other (specify: _______)			Enter unit_code
26.	Is bread available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 28*	|__|	
27.	Select which types of bread are available by entering the price and unit information. If multiple brands of the same product are available, please enter the information for the cheapest brand.			
	Item	**Price**	**Quantity**	**Unit**
27a.	White bread			Enter unit_code
27b.	Brown bread (Whole wheat)			Enter unit_code
27c.	Papadum (flatbread)			Enter unit_code
27d.	Other (specify: ______)			Enter unit_code
28.	Are pasta or rice noodles available for purchase in the shop?	1 = Yes 2 = No *If no, skip to question 30*	|__|	
29.	Select which types of pasta or rice noodles are available by entering the price and unit information. If multiple brands of the same product are available, please enter the information for the cheapest brand.			
	Item	**Price**	**Quantity**	**Unit**

29a.	Pasta noodles (spaghetti or other)			Enter unit_code
29b.	Whole wheat pasta noodles			Enter unit_code
29c.	Rice noodles			Enter unit_code
29d.	Red rice noodles			Enter unit_code
29e.	Other (specify: ________)			Enter unit_code

Nuts and seeds

30.	Are nuts (including coconuts) or seeds available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 32*	|__|
31. If yes, select which nuts and seeds are available by entering the price and unit information (using the same list from the market questionnaire nut and seed list). **Note**: **Please do not include nuts or seeds that are part of snack mixes.**			

Oils

32.	Are cooking oils available for purchase in the shop?	1 = Yes 2 = No *If no, skip to question 35*		|__|
33.	Select which cooking oils are available by entering price and unit information below. If multiple brands of the same product are available, please enter the information for the cheapest brand.			
	Item	**Price**	**Quantity**	**Unit**
33a.	Coconut oil - refined			Enter unit_code
33b.	Coconut oil - virgin			Enter unit_code
33c.	Vegetable oil			Enter unit_code
33d.	Sunflower oil			Enter unit_code
33e.	Palm oil			Enter unit_code
33f.	Canola oil			Enter unit_code
33g.	Soya bean oil			Enter unit_code
33h.	Corn oil			Enter unit_code
33i.	Other (specify: _________)			Enter unit_code
34.	Is adulterated coconut oil available for purchase in the shop?	1 = Yes 2 = No		|__|

Meat

35.	Is fresh meat available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 38*		|__|
36.	Select which fresh meat is available by entering price and unit information			
	Item	**Price**	**Quantity**	**Unit**
36a.	Chicken			Enter unit_code
36b.	Beef			Enter unit_code
36c.	Mutton			Enter unit_code
36d.	Pork			Enter unit_code
36e.	Other (Specify: _________)			Enter unit_code

37.	Is any fresh meat stored in a refrigerator or other cold storage?	1 = Yes 2 = No	|__|
38.	Is frozen meat available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 40*	|__|

39.	Select which frozen meat is available by entering price and unit information. If multiple brands of the same product are available, please enter information for the cheapest brand.			
	Item	**Price**	**Quantity**	**Unit**
39a.	Chicken (broiler, whole)			Enter unit_code
39b.	Chicken (broiler, half)			Enter unit_code
39c.	Chicken (broiler, off cut)			Enter unit_code
39d.	Chicken sausage			Enter unit_code
39e.	Pork sausage			Enter unit_code
39f.	Chicken meatballs			Enter unit_code
39g.	Other (Specify: ________)			Enter unit_code

40.	Are any canned meat products available for purchase in the shop?	1 = Yes 2 = No *If no, skip to question 42*	|__|

41.	Select which canned meat product is available by entering price and unit information:		
	Item	**Price per can**	**Size of can (in grams)**
41a.	Chicken meatballs (or chicken meatball curry)		
41b.	Corned beef		
41c.	Corned mutton		
41d.	Other (Specify: ________)		

Seafood

42.	Is fresh fish available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 44*	|__|
43. If yes, select which fresh fish are available by entering the price and unit information (using the same list from the market questionnaire fresh fish list).			
44.	Is other fresh seafood available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 47*	|__|

45.	Select which other fresh seafood is available by entering price and unit information:			
	Item	**Price**	**Quantity**	**Unit**
45a.	Prawns			Enter unit_code
45b.	Cuttlefish			Enter unit_code
45c.	Other (Specify: ______)			Enter unit_code

46.	Is any fresh fish or other seafood stored in a refrigerator or other cold storage	1 = Yes 2 = No	|__|
47.	Is dried fish available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 49*	|__|

48. If yes, select which dried fish are available by entering the price and unit information (using the same list from the market questionnaire dried fish list)			
49.	Is any frozen seafood (whole or in chunks) available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 51*	| __ |

50.	Select which frozen fish (whole or in chunks) is available by entering price and unit information:			
	Item	**Price**	**Quantity**	**Unit**
50a.	Specify: ___________			Enter unit_code

51.	Are any canned fish or seafood products available for purchase in the shop?	1 = Yes 2 = No *If no, skip to question 53*	| __ |

52.	Select which canned fish or seafood products are available by entering price and unit information (if multiple brands of the same item are available, enter information for the lowest priced brand):		
	Item	**Price per can**	**Size of can (in grams)**
52a.	Canned mackerel		Enter unit_code
52b.	Canned fish curry		Enter unit_code
52c.	Canned sardines		Enter unit_code
52d.	Canned tuna		Enter unit_code
52e.	Salmon		Enter unit_code
52f.	Other (Specify: _________)		Enter unit_code

Eggs

53.	Are fresh eggs available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 55*	| __ |

54.	Select eggs are available by entering price and unit information:			
	Item	**Price**	**Quantity**	**Unit**
54a.	Eggs - White			Enter unit_code
54b.	Eggs - Brown			Enter unit_code
54c.	Eggs – Other (Specify: _______)			Enter unit_code

Milk

55	Is milk available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 64*	| __ |
56	Is fresh milk available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 59*	| __ |
57.	Please enter availability and price information for reference brand (Anchor) FULL CREAM fresh milk. If reference brand is not available, enter information for an alternate brand that is available.		
	Item	**Availability**	**Price**
57a.	Anchor, fresh, full cream, 200 ml	1 = Yes 2 = No	
57b.	Anchor, fresh, full cream, 1,000 ml	1 = Yes	

		2 = No	
57c.	Alternate brand (Specify:_____), fresh, full cream, 200 ml	1 = Yes 2 = No *Relevance: only if 57a. availability = No*	
57d.	Alternate brand (Specify:_____), fresh, full cream, 1,000 ml	1 = Yes 2 = No *Relevance: only if 57b. availability = No*	
58.	Please enter availability and price information for reference brand (Anchor) LOW FAT or NON-FAT fresh milk. If reference brand is not available, enter information for an alternate brand that is available. If no low-fat or non-fat fresh milk options are available, please skip this question by clicking "Next".		
	Item	**Availability**	**Price**
58a.	Anchor, fresh, non-fat, 200 ml	1 = Yes 2 = No	
58b.	Anchor, fresh, non-fat, 1,000 ml	1 = Yes 2 = No	
58c.	Alternate brand (Specify:_____), fresh, non-fat or low fat, 200 ml	1 = Yes 2 = No *Relevance: only if 58a. availability = No*	
58d.	Alternate brand (Specify:_____), fresh, non-fat or low fat, 1,000 ml	1 = Yes 2 = No *Relevance: only if 58b. availability = No*	
59.	Is powdered milk available for purchase in the shop?	1 = Yes 2 = No *If no, skip to question 62*	|__|
60.	Please enter availability and price information for reference brand (Anchor) FULL CREAM powdered milk. If reference brand is not available, enter information for an alternate brand that is available.		
	Item	**Availability**	**Price**
60a.	Anchor, powdered, full cream, 400 g	1 = Yes 2 = No	
60b.	Anchor, powdered, full cream, 1 kg	1 = Yes 2 = No	
60c.	Alternate brand (Specify:_____), powered, full cream, 400 g	1 = Yes 2 = No *Relevance: only if 60a. availability = No*	
60d.	Alternate brand (Specify:_____), powdered full cream, 1 kg	1 = Yes 2 = No *Relevance: only if 60b. availability = No*	
61.	Please enter availability and price information for reference brand (Anchor) LOW FAT or NON-FAT powdered milk. If reference brand is not available, enter information for an alternate brand that		

	is available. If no low-fat or non-fat powdered milk options are available, please skip this question by clicking "Next".		
	Item	**Availability**	**Price**
61a.	Anchor, powdered, non-fat, 400 g	1 = Yes 2 = No	
61b.	Anchor, powdered, 1 kg	1 = Yes 2 = No	
61c.	Alternate brand (Specify:_____), powdered, non-fat or low fat, 400 g	1 = Yes 2 = No *Relevance: only if 61a. availability = No*	
61d.	Alternate brand (Specify:_____), powdered, non-fat or low fat, 1 kg	1 = Yes 2 = No *Relevance: only if 61b. availability = No*	
62.	Is flavored milk available for purchase (in fresh or powdered form)?	1 = Yes 2 = No	|__|
63.	Is fortified milk available for purchase (in fresh or powdered form)?	1 = Yes 2 = No	|__|

Other Dairy Products

64.	Is set or stirred yoghurt available to purchase in the shop?	1 = Yes 2 = No *If no, skip to question 67*	|__|
65.	Please enter availability and price information for reference brand (Ambewela) PLAIN yogurt. If reference brand is not available, enter for an alternate brand that is available.		
	Item	**Availability**	**Price**
65a.	Ambewela, plain, set yogurt, 80 g	1 = Yes 2 = No	|__|
65b.	Alternative brand (Specify:_____), plain, set yogurt, 80 g	1 = Yes 2 = No *Relevance: Only if 65a. availability = No*	|__|
66.	Please enter availability and price information for reference brand (Anchor) LOW FAT yogurt. If reference brand is not available, enter for an alternate brand that is available. If no low-fat or non-fat yogurt options are available, please skip this question by clicking "Next".		
	Item	**Availability**	**Price**
66a.	Anchor, stirred, low fat, 80 g	1 = Yes 2 = No	|__|
66b.	Alternative brand (Specify:_____), low fat, stirred or set yogurt, 80 g	1 = Yes 2 = No *Relevance: Only if 66a. availability = No*	|__|
67.	Is curd available for purchase in the shop	1 = Yes 2 = No *If no, skip to question 69*	|__|
68.	If yes, indicate the price and unit information for curd. If multiple brands of curd are available, please enter the information for the lowest price brand.		

	Item	Price	Quantity	Unit
68a.	Specify brand (or indicate "local" if there is no brand): __________			Enter unit_code

69.	Please indicate the availability of the dairy products below by entering price and unit information. If multiple brands of the same product are available, please enter the information for the cheapest brand.			
	Item	**Price**	**Quantity**	**Unit**
69a.	Drinkable flavored yoghurt			Enter unit_code
69b.	Processed cheese			Enter unit_code
69c.	Butter or margarine			Enter unit_code
69d.	Ghee			Enter unit_code

Ultra-processed foods (packaged and prepared) –

In this final section of the questionnaire, you will be asked to indicate the availability of certain ultra-processed foods. Ultra-processed foods are packaged or prepared foods that are high in sugar, salt, or other industrial substances, but low in nutritional value. For these items, you will not need to provide price information.

Click "next" to continue

70.	Are biscuits available for sale in the shop?	1 = Yes 2 = No *If no, skip to question 72*	|__|
71.	How many biscuit products are available for sale?	Enter the number of products for sale *Note: Please count each product available, including sweet and savory biscuits. Count each brand of the same product type as separate products.*	|__|
72.	Please indicate the availability of the following other types of ultra-processed foods:		
	Item	**Available**	**Not Available**
72a.	Instant noodles (ramen)		
72b.	Cakes		
72c.	Crisps (potato, maize, etc.)		
72d.	Snack mixes (e.g. cocktail, murukku)		
72e.	Popcorn		
72f.	Packaged soya meat		
72g.	Ice cream		
72h.	Chocolate		
72i.	Candies		
72j.	Jam or marmalade		
72k.	Fruit juice (packaged, not fresh)		
73.	Are sugar sweetened beverages (i.e. fizzy drinks) available for sale in the shop?	1 = Yes 2 = No *If no, skip to question 75*	|__|
74.	How many sugar sweetened beverage products are available for sale in the shop	Enter the number of products for sale	|__|

		Note: Please count each product available, including *each brand of the same product type as separate products.*	
75.	Are prepared short eats available for sale in the shop? For example, samosas, roti, wadei/wade, rolls or pastries?	1 = Yes 2 = No	|__|
76.	How many prepared short eats are available for sale in the shop?	Enter the number of products for sale *Note: Please count each product available. Include each different filling of the same type of short eat (e.g. vegetable roti, chicken roti, curry roti) as separate products.*	|__|

Unit_code 1 = Kilograms 2 = Grams 3 = Liters 4 = Milliliters 5 = Each/per unit 6 = Bunch

Appendix 1.4. Survey food list, FBDG, RCP, and NEMS-S groupings

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Ambarella	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Apple - Green	x	x	Fruit	Other fruits	Group 1
Apple - Red	x	x	Fruit	Other fruits	Group 1
Avocado	x	x	Fruit	Other fruits	Group 1
Banana – Ambul	x	x	Fruit	Other fruits	Group 1
Banana – Ambun	x	x	Fruit	Other fruits	Group 1
Banana – Anamalu	x	x	Fruit	Other fruits	Group 1
Banana – Kolikuttu	x	x	Fruit	Other fruits	Group 1
Banana – Seeni	x	x	Fruit	Other fruits	Group 1
Banana – Other (Specify)	x	x	Fruit	Other fruits	Group 1
Cashew Apple	x	x	Fruit	Other fruits	Group 1
Dates	x	x	Fruit	Other fruits	Group 1
Durian	x	x	Fruit	Other fruits	Group 1
Goraka	x	x	n/a	n/a	Group 1
Grapes	x	x	Fruit	Other fruits	Group 1
Guava	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Jackfruit	x	x	Fruit	Other fruits	Group 1
King coconut	x	x	Fruit	Other fruits	Group 1
Lemon	x	x	n/a	n/a	Group 1
Lime	x	x	n/a	n/a	Group 1
Mango – Betti	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Mango - Karthakolomban	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Mango – Kohu	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Mango – Vilad	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Mango – Other (Specify)	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Mangosteen	x	x	Fruit	Other fruits	Group 1
Melon	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Orange	x	x	Fruit	Other fruits	Group 1
Papaya (Papaw)	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Passion fruit	x	x	Fruit	Vit-A rich fruits & veg	Group 1
Pineapple - small	x	x	Fruit	Other fruits	Group 1
Pineapple - medium	x	x	Fruit	Other fruits	Group 1
Pineapple - large	x	x	Fruit	Other fruits	Group 1
Rambutan	x	x	Fruit	Other fruits	Group 1
Slime apple (Bael/Beli)	x	x	Fruit	Other fruits	Group 1
Soursop	x	x	Fruit	Other fruits	Group 1
Wood apple	x	x	Fruit	Other fruits	Group 1
Ash plantain	x	x	Vegetable	Vegetables	Group 1

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Bandakka (Ladies Fingers)	x	x	Vegetable	Vegetables	Group 1
Beans (Green)	x	x	Vegetable	Vegetables	Group 1
Beetroot	x	x	Vegetable	Vegetables	Group 1
Bitter Gourd	x	x	Vegetable	Vegetables	Group 1
Brinjal	x	x	Vegetable	Vegetables	Group 1
Cabbage	x	x	Vegetable	Vegetables	Group 1
Capsicum	x	x	Vegetable	Vegetables	Group 1
Carrot	x	x	Vegetable	Vit-A rich fruits & veg	Group 1
Cauliflower	x	x	Vegetable	Vegetables	Group 1
Cucumber	x	x	Vegetable	Vegetables	Group 1
Dambala	x	x	Vegetable	Vegetables	Group 1
Drumstick	x	x	Vegetable	Vegetables	Group 1
Elabattu	x	x	Vegetable	Vegetables	Group 1
Green Chillies	x	x	n/a	n/a	Group 1
Kekiri	x	x	Vegetable	Vegetables	Group 1
Knol Khol	x	x	Vegetable	Vegetables	Group 1
Kohila Yams	x	x	Vegetable	Vegetables	Group 1
Leeks	x	x	Vegetable	Vegetables	Group 1
Long Beans	x	x	Vegetable	Vegetables	Group 1
Mushroom - Button	x	x	Vegetable	Vegetables	Group 1
Mushroom - Other (Specify)	x	x	Vegetable	Vegetables	Group 1
Mushroom - Oyster	x	x	Vegetable	Vegetables	Group 1
Plantain Flower	x	x	Vegetable	Vegetables	Group 1
Radish	x	x	Vegetable	Vegetables	Group 1
Ridge Gourd (Luffa)	x	x	Vegetable	Vegetables	Group 1
Snake Gourd	x	x	Vegetable	Vegetables	Group 1
Sweet Pumpkin	x	x	Vegetable	Vit-A rich fruits & veg	Group 1
Thibbatu	x	x	Vegetable	Vegetables	Group 1
Thumba Karawila	x	x	Vegetable	Vegetables	Group 1
Tomatoes	x	x	Vegetable	Vegetables	Group 1
Canned Corn	x		Vegetable	Vegetables	Group 1
Canned Green peas	x		Vegetable	Vegetables	Group 1
Canned Mushrooms	x		Vegetable	Vegetables	Group 1
Canned Beans (baked)	x		Vegetable	Vegetables	Group 1
Canned Beans (green)	x		Vegetable	Vegetables	Group 1
Canned vegetables other (Specify)	x		Vegetable	Vegetables	Group 1
Cabbage leaves	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Gotukola	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Kankun	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Katurumurunga	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Kohila leaves	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Mukunuwenna	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Nivithi	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Onion leaves	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Sarana	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Thampala	x	x	Vegetable (leafy)	Green leafy vegetables	Group 1
Chickpea	x	x	Protein – pulse	Pulses	Group 1
Cowpea - Red	x	x	Protein – pulse	Pulses	Group 1
Cowpea - White	x	x	Protein – pulse	Pulses	Group 1
Dhal - Green	x	x	Protein – pulse	Pulses	Group 1
Dhal - Red	x	x	Protein – pulse	Pulses	Group 1
Dhal - Yellow	x	x	Protein – pulse	Pulses	Group 1
Gram - Black	x	x	Protein – pulse	Pulses	Group 1
Gram - Green	x	x	Protein – pulse	Pulses	Group 1
Gram - Other (specify)	x	x	Protein – pulse	Pulses	Group 1
Soya Bean	x	x	Protein – pulse	Pulses	Group 1
Other pulse (specify)	x	x	Protein – pulse	Pulses	Group 1
Balaya	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Emperor	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Hurulla	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Karalla/Katuwalla	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Kelavalla	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Kumbalawa/Angila	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Lula	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Mora	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Mullet	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Paraw	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Salaya/Sudaya	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Seer	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Sprats	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Teppili/Tilapiya/Korali	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Thalapath	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Other fresh fish (Specify)	x	x	Protein – fish (fresh)	Fresh fish and seafood	Group 1
Sprats	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Keerameen	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Salaya	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Hurulla	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Thalapath	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Seer	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Katta	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Koduwa	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Anjila	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Balaya	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Mora/Keelan	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Paraw	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Anguluwa	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Other dried fish (Specify)	x	x	Protein – fish (dried)	Dried and canned fish	Group 2
Tuna	x		Protein – fish (frozen)	n/a	Group 1
Seer	x		Protein – fish (frozen)	n/a	Group 1
Thalapath	x		Protein – fish (frozen)	n/a	Group 1
Other frozen fish (Specify)	x		Protein – fish (frozen)	n/a	Group 1
Canned mackerel	x	x	Protein – fish (canned)	Fresh fish and seafood	Group 1
Canned fish curry	x	x	Protein – fish (canned)	Fresh fish and seafood	Group 1
Canned sardines	x	x	Protein – fish (canned)	Fresh fish and seafood	Group 1
Canned tuna	x	x	Protein – fish (canned)	Fresh fish and seafood	Group 1
Salmon	x	x	Protein – fish (canned)	Fresh fish and seafood	Group 1
Other canned fish (Specify)	x		Protein – fish (canned)	Fresh fish and seafood	Group 1
Prawns	x	x	Protein – seafood (fresh)	Fresh fish and seafood	Group 1

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Cuttlefish	x	x	Protein – seafood (fresh)	Fresh fish and seafood	Group 1
Crabs		x	Protein – seafood (fresh)	Fresh fish and seafood	n/a
Linna		x	Protein – seafood (fresh)	Fresh fish and seafood	n/a
Maduwa		x	Protein – seafood (fresh)	Fresh fish and seafood	n/a
Other fresh seafood (Specify)	x		Protein – seafood (fresh)	Fresh fish and seafood	Group 1
Chicken	x	x	Protein – meat (fresh)	Meat	Group 1
Beef	x	x	Protein – meat (fresh)	Meat	Group 1
Mutton	x	x	Protein – meat (fresh)	Meat	Group 1
Pork	x	x	Protein – meat (fresh)	Meat	Group 1
Other fresh meat (Specify)	x		Protein – meat (fresh)	Meat	Group 1
Chicken (broiler, whole)	x		Protein – meat (frozen)	Meat	Group 1
Chicken (broiler, half)	x		Protein – meat (frozen)	Meat	Group 1
Chicken (broiler, off cut)	x		Protein – meat (frozen)	Meat	Group 1
Chicken sausage	x	x	Protein – meat (fresh or frozen)	Meat	Group 3
Pork sausage	x	x	Protein – meat (fresh or frozen)	Meat	Group 3
Chicken meatballs	x		Protein – meat (frozen)	Meat	Group 3
Other frozen meat (Specify)	x		Protein – meat (frozen)	Meat	Group 3
Chicken meatballs (or chicken meatball curry)	x	x	Protein – meat (canned)	Meat	Group 3
Corned beef	x		Protein – meat (canned)	Meat	Group 3
Corned mutton	x		Protein – meat (canned)	Meat	Group 3
Other canned meat (Specify)	x		Protein – meat (canned)	Meat	Group 3
Eggs - White	x	x	Protein – eggs	Eggs	Group 1
Eggs - Brown	x	x	Protein – eggs	Eggs	Group 1
Eggs – Other (Specify)	x		Protein – eggs	Eggs	Group 1
Barley	x	x	Starchy staples	n/a	Group 1
Finger Millet	x	x	Starchy staples	n/a	Group 1
Maize	x	x	Starchy staples	Starchy staples maize/manioc/ potato	Group 1

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Rice - Basmathi	x	x	Starchy staples	Starchy staples - rice	Group 1
Rice - Kekulu Samba, red	x	x	Starchy staples	Starchy staples - rice	Group 2
Rice - Kekulu Samba, white	x	x	Starchy staples	Starchy staples - rice	Group 2
Rice - Kekulu, red	x	x	Starchy staples	Starchy staples - rice	Group 2
Rice - Kekulu, white	x	x	Starchy staples	Starchy staples - rice	Group 2
Rice - Nadu, red	x	x	Starchy staples	Starchy staples - rice	Group 1
Rice - Nadu, white	x	x	Starchy staples	Starchy staples - rice	Group 1
Rice - Samba	x	x	Starchy staples	Starchy staples - rice	Group 1
Rice - Other (Specify)	x	x	Starchy staples	Starchy staples - rice	Group 1/ Group 2
Sago	x	x	Starchy staples	n/a	Group 1
Wheat (whole grain)	x	x	Starchy staples	Starchy staples - wheat	Group 1
White rice flour	x	x	Starchy staples	Starchy staples - rice	Group 2
Red rice flour	x	x	Starchy staples	Starchy staples - rice	Group 1 (red rice – whole)
Wheat flour (white)	x	x	Starchy staples	Starchy staples - wheat	Group 2
Whole wheat flour (atta)	x	x	Starchy staples	Starchy staples - wheat	Group 1
Kurakkan flour (millet)	x	x	Starchy staples	n/a	Group 1
Gram flour (chickpea)	x	x	Protein - pulses	Pulses	Group 1
Ulundu flour (lentil)	x	x	Protein - pulses	Pulses	Group 1
Other flour (Specify)	x		Starchy staples	n/a	n/a
White bread	x	x	Starchy staples	Starchy staples - wheat	Group 3
Brown bread (whole wheat)	x	x	Starchy staples	Starchy staples - wheat	Group 2
Papadum (flatbread)	x	x	Starchy staples	Starchy staples - wheat	n/a
Other bread (Specify)	x		Starchy staples	n/a	n/a
Garlic	x	x	n/a	n/a	n/a
Innala	x	x	Starchy staples	Starchy staples maize/manioc/ potato	n/a
Kiriala	x	x	Starchy staples	n/a	n/a
Manioc	x	x	Starchy staples	Starchy staples maize/manioc/ potato	n/a
Onion - Big	x	x	Starchy staples	n/a	n/a
Onion - Red	x	x	Starchy staples	n/a	n/a

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Potato	x	x	Starchy staples	Starchy staples maize/manioc/ potato	n/a
Sweet Potato	x	x	Starchy staples	Vit-A rich fruits & veg	n/a
Yam	x	x	Starchy staples	n/a	n/a
Pasta noodles (spaghetti or other)	x	x	Starchy staples	Starchy staples - wheat	Group 2
Whole wheat pasta noodles	x		Starchy staples	Starchy staples - wheat	Group 1
Rice noodles	x	x	Starchy staples	Starchy staples - rice	Group 2
Red rice noodles	x	x	Starchy staples	Starchy staples - rice	Group 1 (red rice – whole)
Other noodles (Specify)	x		Starchy staples	n/a	n/a
Milk, fresh, whole	x	x	Dairy	Milk	Group 1
Milk, fresh, low-fat	x	x	Dairy	Milk	Group 1
Milk, powdered, whole	x	x	Dairy	Milk	Group 1
Milk, powdered, low-fat	x	x	Dairy	Milk	Group 1
Yogurt, set, whole	x	x	Dairy	Other dairy	Group 1
Yogurt, set, lowfat	x		Dairy	Other dairy	Group 1
Yogurt, drinkable	x		Dairy	Other dairy	Group 3
Curd		x	Dairy	Other dairy	n/a
Malted drink	x		n/a	n/a	Group 3
Cheese, processed	x		Dairy	Other dairy	Group 3
Butter or margarine	x	x	Nuts & oils	Oils	n/a
Ghee	x	x	Nuts & oils	Oils	n/a
Coconut - small	x	x	Nuts & oils	Nuts	Group 1
Coconut - large	x	x	Nuts & oils	Nuts	Group 1
Cashew (Cadju)	x	x	Nuts & oils	Nuts	Group 1
Groundnut (Peanuts)	x	x	Nuts & oils	Nuts	Group 1
Pumpkin Seeds	x	x	Nuts & oils	Nuts	Group 1
Gingelly Seeds (Sesame)	x	x	Nuts & oils	Nuts	Group 1
Coconut oil - refined	x	x	Nuts & oils	Oils	Group 2
Coconut oil - virgin	x	x	Nuts & oils	Oils	Group 2
Vegetable oil	x	x	Nuts & oils	Oils	Group 2
Sunflower oil	x	x	Nuts & oils	Oils	Group 2
Palm oil	x		Nuts & oils	Oils	Group 2
Canola oil	x	x	Nuts & oils	Oils	Group 2
Soya bean oil	x	x	Nuts & oils	Oils	Group 2
Corn oil	x	x	Nuts & oils	Oils	Group 2
Other oil (Specify)	x		Nuts & oils	Oils	Group 2
Instant noodles (ramen)	x		n/a	n/a	Group 3
Cakes	x		n/a	n/a	Group 3
Crisps (potato, maize, etc.)	x		n/a	n/a	Group 3
Snack mixes (e.g. cocktail, murukku)	x		n/a	n/a	Group 3

Food item	Retail shop survey	Market survey	FBDG used in CoRD	RCP food category	NEM-S classification
Popcorn	x		n/a	n/a	Group 3
Packaged soya meat	x		n/a	n/a	Group 3
Ice cream	x		n/a	n/a	Group 3
Chocolate	x		n/a	n/a	Group 3
Candies	x		n/a	n/a	Group 3
Jam or marmalade	x		n/a	n/a	Group 3
Fruit juice (packaged, not fresh)	x		n/a	n/a	Group 3
Sugar		x	n/a	Sugar	n/a
Treacle		x	n/a	n/a	n/a
Jaggery		x	n/a	n/a	n/a
Honey		x	n/a	n/a	n/a
Coconut milk		x	n/a	n/a	n/a
Dried chilies		x	n/a	n/a	n/a
Salt		x	n/a	n/a	n/a

Appendix 2. Aim 1 Supplementary Tables and Figures

Appendix 2.1. Availability and item counts for detailed food groups, December 2020

Appendix 2.2. Lowest cost food items selected for CoRD, by Grama Niladhari Division, December 2020

Appendix 2.3. Cost of food group recommendations, convenience, and preference premiums, December 2020

Appendix 2.1. Availability and item counts for detailed food groups, December 2020

	Fruits (23 items)		Vegetables (30 items)		Green leafy vegetables (10 items)		Vitamin-A rich fruits and vegetables (9 items)		Pulses (13 items)	
	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count
Markets										
Batticaloa	75%	5.5	100%	12.8	75%	1.5	100%	4.3	100%	4.3
Mannar	100%	2.0	100%	21.5	100%	3.0	100%	4.5	50%	0.5
Matale	100%	5.6	100%	20.8	100%	9.0	100%	5.4	100%	3.2
Monaragala	100%	8.0	100%	22.5	100%	4.0	100%	5.5	100%	5.5
Mullaitivu	100%	10.3	100%	21.7	100%	7.7	100%	5.7	100%	6.7
Total	94%	6.3	100%	19.3	94%	5.5	100%	5.1	94%	4.1
Retail Shops										
Batticaloa	9%	0.1	31%	1.2	3%	0.0	11%	0.2	100%	2.0
Mannar	32%	0.4	28%	1.6	0%	0.0	28%	0.3	96%	1.6
Matale	0%	0.0	43%	1.7	0%	0.0	22%	0.3	100%	1.9
Monaragala	50%	0.8	33%	1.0	0%	0.0	67%	1.0	100%	3.4
Mullaitiviu	44%	0.5	56%	2.3	4%	0.1	19%	0.4	93%	2.5
Total	24%	0.3	39%	1.6	2%	0.0	24%	0.3	97%	2.2
Food environments										
Batticaloa	100%	9.0	100%	14.8	100%	2.6	100%	5.2	100%	6.3
Mannar	100%	3.2	100%	22.1	100%	4.0	100%	5.0	100%	3.0
Matale	100%	8.0	100%	20.6	100%	10.0	100%	5.9	100%	5.3
Monaragala	100%	11.0	100%	23.0	100%	5.0	100%	6.0	100%	6.8
Mullaitivu	100%	12.8	100%	23.3	100%	8.5	100%	7.3	100%	8.2
Total	100%	8.6	100%	20.2	100%	5.9	100%	5.8	100%	5.8

	Fresh fish and seafood (21 items)		Dried or canned fish (19 items)		Meat (7 items)		Eggs (2 items)		Grains (6 items)	
	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count
Markets										
Batticaloa	0%	0.0	75%	1.8	0%	0.0	75%	1.5	75%	1.8
Mannar	0%	0.0	50%	3.5	50%	0.5	50%	0.5	50%	1.0
Matale	100%	7.0	100%	8.2	20%	0.4	100%	1.4	20%	0.4
Monaragala	100%	4.5	100%	4.0	50%	1.5	100%	2.0	100%	2.5
Mullaitivu	100%	14.7	100%	5.0	100%	2.3	100%	2.0	100%	4.0
Total	63%	5.5	88%	4.9	38%	0.8	88%	1.5	56%	1.6
Retail Shops										
Batticaloa	0%	0.0	86%	1.1	0%	0.0	80%	0.9	66%	1.2
Mannar	0%	0.0	40%	0.6	0%	0.0	76%	1.0	68%	1.4
Matale	13%	0.2	100%	2.7	4%	0.1	83%	1.0	65%	1.3
Monaragala	8%	0.1	92%	2.7	8%	0.1	100%	1.3	92%	1.8
Mullaitiviu	0%	0.0	70%	1.0	0%	0.0	56%	0.7	89%	2.1
Total	3%	0.0	77%	1.4	2%	0.0	76%	0.9	74%	1.5
Food environments										
Batticaloa	0%	0.0	100%	6.1	0%	0.0	100%	2.0	100%	1.0
Mannar	0%	0.0	100%	8.6	100%	1.0	100%	1.5	100%	1.0
Matale	100%	10.0	100%	10.0	88%	1.8	100%	1.9	88%	0.9
Monaragala	100%	6.0	100%	6.3	100%	3.0	100%	2.0	100%	2.0
Mullaitivu	100%	16.6	100%	7.1	100%	2.3	100%	2.0	100%	2.0
Total	51%	6.4	100%	7.6	71%	1.4	100%	1.9	98%	1.3

	Roots and tubers (7 items)		Bread, flour, noodles (9 items)		Milk (4 items)		Other dairy (3 items)		Nuts and seeds (5 items)		Oils (7 items)	
	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count	Available (y/n)	Mean count
Markets												
Batticaloa	100%	4.0	100%	2.3	25%	0.3	0%	0.0	75%	1.3	100%	1.5
Mannar	100%	5.0	50%	2.0	0%	0.0	50%	1.0	100%	1.0	50%	0.5
Matale	100%	4.4	80%	1.4	0%	0.0	0%	0.0	100%	1.0	100%	1.0
Monaragala	100%	5.5	100%	6.5	50%	1.0	100%	1.5	100%	1.5	50%	0.5
Mullaitivu	100%	6.3	100%	6.7	100%	2.3	100%	2.0	100%	3.0	100%	3.3
Total	100%	4.9	81%	3.1	31%	0.6	31%	0.6	94%	1.5	81%	1.4
Retail Shops												
Batticaloa	91%	2.0	91%	1.5	3%	0.0	29%	0.3	71%	0.8	37%	0.6
Mannar	92%	2.0	96%	3.2	8%	0.1	60%	1.0	60%	0.7	88%	1.5
Matale	100%	2.2	96%	2.4	43%	0.4	74%	1.0	78%	0.8	91%	0.9
Monaragala	100%	3.0	100%	4.7	75%	1.0	92%	1.5	100%	1.2	83%	1.4
Mullaitiviu	93%	2.5	100%	2.4	0%	0.0	41%	0.6	78%	1.0	96%	1.5
Total	94%	2.3	96%	2.5	18%	0.2	52%	0.8	75%	0.8	75%	1.1
Food environments												
Batticaloa	100%	4.0	100%	4.8	50%	0.5	67%	0.8	100%	2.2	100%	2.5
Mannar	100%	4.0	100%	3.7	20%	0.2	100%	1.6	100%	1.2	100%	2.3
Matale	100%	4.0	100%	4.3	75%	0.8	100%	1.5	100%	1.1	100%	1.0
Monaragala	100%	4.0	100%	5.0	100%	2.0	100%	3.0	100%	2.0	100%	2.8
Mullaitivu	100%	4.0	100%	6.8	100%	2.3	100%	2.2	100%	3.3	100%	4.2
Total	100%	4.0	100%	5.0	64%	1.0	84%	1.6	100%	2.0	100%	2.6

Appendix 2.2. Lowest cost food items selected for CoRD, by Grama Niladhari Division, December 2020

District	GN	Fruit		Vegetables		Leafy Veg	Protein	
Batticaloa	Ayithiyamalai North	Banana	.	Cabbage	Snake gourd	Onion leaves	Yellow dhal	Dried sprats
Batticaloa	Ayithiyamalai South	Banana	Dates	Cabbage	Leeks	Cabbage leaves	Dried fish – other	Yellow dhal
Batticaloa	Ilupadichenai	Banana	Dates	Cabbage	Dambala	Cabbage leaves	Dried fish - other	Yellow dhal
Batticaloa	Kanthinagar	Banana	Wood apple	Cabbage	Dambala	Thampala	Red dhal	Dried keerameen fish
Batticaloa	Karaveddy	Banana	Dates	Cabbage	Snake gourd	Cabbage leaves	Dried fish – other	Yellow dhal
Batticaloa	Kothiyapulai	Banana	Dates	Cabbage	Dambala	Cabbage leaves	Dried fish other	Yellow dhal
Batticaloa	Mahilavedduvan	Banana	.	Cabbage	Snake gourd	Mukunu-wenna	Red dhal	Dried angila fish
Batticaloa	Nediyamadu	Banana	.	Cabbage	Snake gourd	Mukunu-wenna	Red dhal	Dried sprats
Batticaloa	Pavakkodichenai	Banana	Dates	Cabbage	Dambala	Cabbage leaves	Dried fish other	Yellow dhal
Batticaloa	Puthumandapathady	Banana	Dates	Cabbage	Dambala	Cabbage leaves	Dried fish other	Yellow dhal
Batticaloa	Unnichchei	Banana	Dates	Cabbage	Leeks	Cabbage leaves	Dried fish other	Yellow dhal
Batticaloa	Vilavedduwan	Banana	Dates	Cabbage	Snake gourd	Cabbage leaves	Dried fish other	Yellow dhal
Mannar	Ahathymurippu	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Dried angila fish	Dried angila fish
Mannar	Kokkupadayan	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Red dhal	Dried angila fish
Mannar	Koolankulam	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Red dhal	Dried angila fish
Mannar	Marichchukaddy	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Dried angila fish	Dried angila fish
Mannar	Maruthamadhu	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Red dhal	Dried angila fish

District	GN	Fruit		Vegetables		Leafy Veg	Protein	
Mannar	Mullikulam	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Dried angila fish	Dried angila fish
Mannar	Palaikuly	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Dried fish – other	Yellow dhal
Mannar	P.P. Potkerny	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Red dhal	Dried angila fish
Mannar	S.P. Potkerny	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Red dhal	Dried angila fish
Mannar	Veppankulam	Mango	Papaya	Cucumber	Kekiri	Mukunu-wenna	Dried salaya fish	Red dhal
Matale	Guruwelayaya	Mango	Banana	Cabbage	Sweet pumpkin	Thampala	Yellow dhal	Dried fish – other
Matale	Himbiliyakada	Banana	Papaya	Cabbage	Sweet pumpkin	Thampala	Yellow dhal	Dried sprats
Matale	Kumbukoya	Mango	Banana	Sweet pumpkin	Cabbage	Thampala	Yellow dhal	dfish_other
Matale	Lediyangala	Mango	Banana	Cabbage	Sweet pumpkin	Thampala	Pulse – other	Dried sprats
Matale	Naminigama	Banana	Papaya	Cabbage	Sweet pumpkin	Thampala	Yellow dhal	Dried sprats
Matale	Naminioya	Banana	Papaya	Cabbage	Sweet pumpkin	Thampala	Yellow dhal	Dried sprats
Matale	Sonutta	Banana	Papaya	Cabbage	Sweet pumpkin	Thampala	Yellow dhal	Dried sprats
Matale	Sulugune	Mango	Papaya	Sweet pumpkin	Cabbage	Thampala	Pulse – other	Dried fish - other
Monaragala	Aluthwewa	Mango	Banana	Tomato	Cabbage	Mukunu-wenna	Yellow dhal	Dried sprats
Monaragala	Hambegamuwa	Mango	Banana	Tomato	Cabbage	Mukunu-wenna	Yellow dhal	Dried sprats
Monaragala	Kandiyapitawewa	Mango	Banana	Tomato	Cabbage	Mukunu-wenna	Red dhal	Dried sprats
Monaragala	Kotaweheramankada	Mango	Banana	Tomato	Cabbage	Mukunu-wenna	Red dhal	Dried sprats
Mullaitivu	Amaithipuram	Banana	Papaya	Cabbage	Tomato	Cabbage leaves	Green dhal	Dried fish - other
Mullaitivu	Ampalapperumalkulam	Papaya	Banana	Kekiri	Cucumber	Cabbage leaves	Red dhal	Dried sprats

District	GN	Fruit		Vegetables		Leafy Veg	Protein	
Mullaitivu	Iyankankulam	Papaya	Wood apple	Kekiri	Tomato	Thampala	Green dhal	Dried sprats
Mullaitivu	Kalvilan	Papaya	Banana	Kekiri	Cucumber	Cabbage leaves	Red dhal	Dried salaya fish
Mullaitivu	Koddaikaddiyakulam	Papaya	Banana	Kekiri	Cucumber	Cabbage leaves	Red dhal	Dried sprats
Mullaitivu	Puththuvedduvan	Papaya	Wood apple	Ladies fingers	Kekiri	Thampala	Green dhal	Dried hurulla fish
Mullaitivu	Thenniyankulam	Papaya	Banana	Kekiri	Cucumber	Cabbage leaves	Red dhal	Dried sprats
Mullaitivu	Thirunagar	Papaya	Banana	Cucumber	Kekiri	Mukunu-wenna	Red dhal	Dried sprats
Mullaitivu	Thunukkai	Papaya	Banana	Kekiri	Cucumber	Cabbage leaves	Red dhal	Dried sprats
Mullaitivu	Uyilankulam	Papaya	Banana	Kekiri	Cucumber	Cabbage leaves	Red dhal	Dried balaya fish
Mullaitivu	Yogapuram Centre	Papaya	Banana	Ladies fingers	Kekiri	Cabbage leaves	Green dhal	Dried sprats

District	GN	Starchy staples		Dairy	Nuts & oils
Batticaloa	Ayithiyamalai North	Wheat flour - atta	Rice – white, nadu	Powdered milk - full	Coconut
Batticaloa	Ayithiyamalai South	Wheat flour - atta	Rice – white, nadu	Powdered milk - full	Coconut
Batticaloa	Ilupadichenai	Wheat flour - white	Sweet potato	Yogurt	Coconut
Batticaloa	Kanthinagar	Wheat flour - atta	Sweet potato	.	Coconut
Batticaloa	Karaveddy	Wheat flour - atta	Rice – white, nadu	Powdered milk - full	Coconut
Batticaloa	Kothiyapulai	Wheat flour - white	Sweet potato	.	Coconut
Batticaloa	Mahilavedduvan	Wheat flour - atta	Rice – white, nadu	Powdered milk - full	Coconut
Batticaloa	Nediyamadu	Wheat flour - atta	Manioc	Powdered milk - full	Coconut
Batticaloa	Pavakkodichenai	Wheat flour - white	Sweet potato	Yogurt	Coconut
Batticaloa	Puthumandapathady	Wheat flour - white	Sweet potato	Yogurt	Coconut
Batticaloa	Unnichchei	Wheat flour - atta	Rice – kekulu, white	Yogurt	Coconut
Batticaloa	Vilavedduwan	Wheat flour - atta	Rice – nadu, white	Powdered milk - full	Coconut
Mannar	Ahathymurippu	Wheat flour - white	Rice – nadu, red	Drinkable yogurt	Coconut
Mannar	Kokkupadayan	Wheat flour - white	Rice – white, nadu	Drinkable yogurt	Coconut
Mannar	Koolankulam	Wheat flour - white	Rice – nadu, red	Drinkable yogurt	Coconut
Mannar	Marichchukaddy	Wheat flour - white	Rice – white, nadu	Yogurt	Coconut
Mannar	Maruthamadhu	Wheat flour - white	Rice – white, nadu	Powdered milk - full	Coconut
Mannar	Mullikulam	Wheat flour - white	Rice – white, nadu	Yogurt	Coconut
Mannar	Palaikuly	Wheat flour - white	Rice - other	Drinkable yogurt	Coconut
Mannar	P.P. Potkerny	Wheat flour - white	Rice - other	Yogurt	Coconut
Mannar	S.P. Potkerny	Wheat flour - white	Rice – white, nadu	Yogurt	Coconut
Mannar	Veppankulam	Wheat flour - white	Rice – nadu, red	Powdered milk - full	Coconut
Matale	Guruwelayaya	Wheat flour - white	Sweet potato	Powdered milk - full	Coconut
Matale	Himbiliyakada	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Matale	Kumbukoya	Wheat flour - white	Sweet potato	Yogurt	Coconut
Matale	Lediyangala	Wheat flour - white	Sweet potato	Powdered milk - full	Coconut
Matale	Naminigama	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Matale	Naminioya	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Matale	Sonutta	Wheat flour - white	Manioc	Powdered milk - full	Coconut

District	GN	Starchy staples		Dairy	Nuts & oils
Matale	Sulugune	Wheat flour - white	Sweet potato	Yogurt	Coconut
Monaragala	Aluthwewa	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Monaragala	Hambegamuwa	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Monaragala	Kandiyapitawewa	Wheat flour - white	Rice - other	Powdered milk - full	Coconut
Monaragala	Kotaweheramankada	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Amaithipuram	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Mullaitivu	Ampalapperumalkulam	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Iyankankulam	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Mullaitivu	Kalvilan	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Koddaikaddiyakulam	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Puththuvedduvan	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Mullaitivu	Thenniyankulam	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Thirunagar	Wheat flour - white	Manioc	Powdered milk - full	Coconut
Mullaitivu	Thunukkai	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Uyilankulam	Wheat flour - white	Rice – kekulu, white	Powdered milk - full	Coconut
Mullaitivu	Yogapuram Centre	Wheat flour - white	Rice – kekulu, white	Curd	Coconut

Appendix 2.3. Cost of food group recommendations, convenience, and preference premiums, December 2020

	(a) CoRD *LKR*	(b) CoRD – 1 market *LKR*	*Convenience premium* (b)/(a)	(c) CoRD – FP *LKR*	*Preference premium* (c)/(a)
Fruits	20.50	22.09	1.10	46.12	2.33
Vegetables	34.71	41.09	1.23	76.64	2.34
Protein foods	17.72	22.39	1.41	82.54	4.94
Starchy staples	30.02	30.61	1.02	66.13	2.25
Dairy	49.77	50.96	1.02	56.13	1.15
Nuts and oils	4.81	4.84	1.01	12.42	3.21

* LKR 59 is equivalent to $1 in 2011 purchasing power parity (PPP) terms

Appendix 3. Aim 2 Supplementary Tables and Figures

Appendix 3.1. Food group variety (counts) in 45 Grama Niladhari Divisions, by month of follow up and outlet type

	Dec '20	Jan '21	Feb '21	Mar '21	Apr '21	Jul '21	Sep '21	Oct '21	Nov '21	Dec '21	% Decrease Max month - Min month
Average item count:											
Traditional markets											
Fruit	6.5	5.8	7.8	7.4	7.6	7.1	6.4	4.8	5.3	5.9	39%
Vegetables	18.3	15.9	17.2	19.0	17.9	16.9	15.1	16.3	15.3	16.2	21%
Leafy vegetables	5.9	4.2	3.9	5.0	4.7	4.1	3.4	4.4	3.9	4.2	41%
Pulses	4.5	4.5	4.4	4.9	4.3	3.5	3.6	3.8	3.2	3.9	35%
Fish	11.7	9.8	10.5	10.3	10.7	8.7	9.7	9.5	8.9	10.4	26%
Meat	2.2	1.9	2.2	2.3	1.9	2.0	2.3	2.0	2.3	1.7	29%
Egg	1.7	1.6	1.6	1.5	1.6	1.7	1.6	1.7	1.5	1.5	15%
Grains	3.9	4.9	5.3	5.1	4.6	4.0	3.4	2.9	3.3	3.5	44%
Roots & tubers	4.2	3.9	3.9	4.3	4.2	3.1	3.7	3.6	3.6	3.5	28%
Dairy	2.5	2.3	1.8	1.9	1.9	2.0	2.3	1.8	2.3	2.2	28%
Nuts	1.6	1.6	1.7	1.4	1.7	1.5	1.6	1.4	1.5	1.5	18%
Oils	1.9	1.9	2.2	1.6	1.7	1.5	1.9	1.7	1.5	1.3	40%
Village retail shops:											
Fruit	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.3	1.2	14%
Vegetables	4.1	3.7	2.6	2.9	3.5	3.4	3.3	3.3	3.4	2.8	35%
Leafy vegetables	1.5	0	0	0	0	0	0	1.0	1.0	1.0	100%
Pulses	2.5	2.3	2.2	2.3	2.2	1.9	1.5	1.7	2.2	1.8	42%
Fish	2.6	2.6	2.3	2.2	2.6	2.3	1.8	1.9	2.0	2.0	30%
Meat	1.9	1.8	1.7	1.7	1.8	1.3	1.1	1.1	1.2	1.1	44%
Egg	1.2	1.2	1.3	1.3	1.3	1.2	1.1	1.1	1.2	1.1	17%
Grains	3.4	3.4	3.3	3.5	3.3	3.0	2.7	2.8	3.1	2.8	21%
Roots & tubers	2.1	2.0	2.0	1.9	1.9	2.0	1.9	1.9	1.9	1.9	12%
Dairy	1.8	1.8	1.7	1.6	1.7	1.8	1.4	1.8	1.9	1.9	28%
Nuts	1.1	1.2	1.1	1.0	1.1	1.1	1.0	1.0	1.1	1.1	16%
Oils	1.6	1.5	1.5	1.5	1.4	1.3	1.3	1.3	1.3	1.2	29%

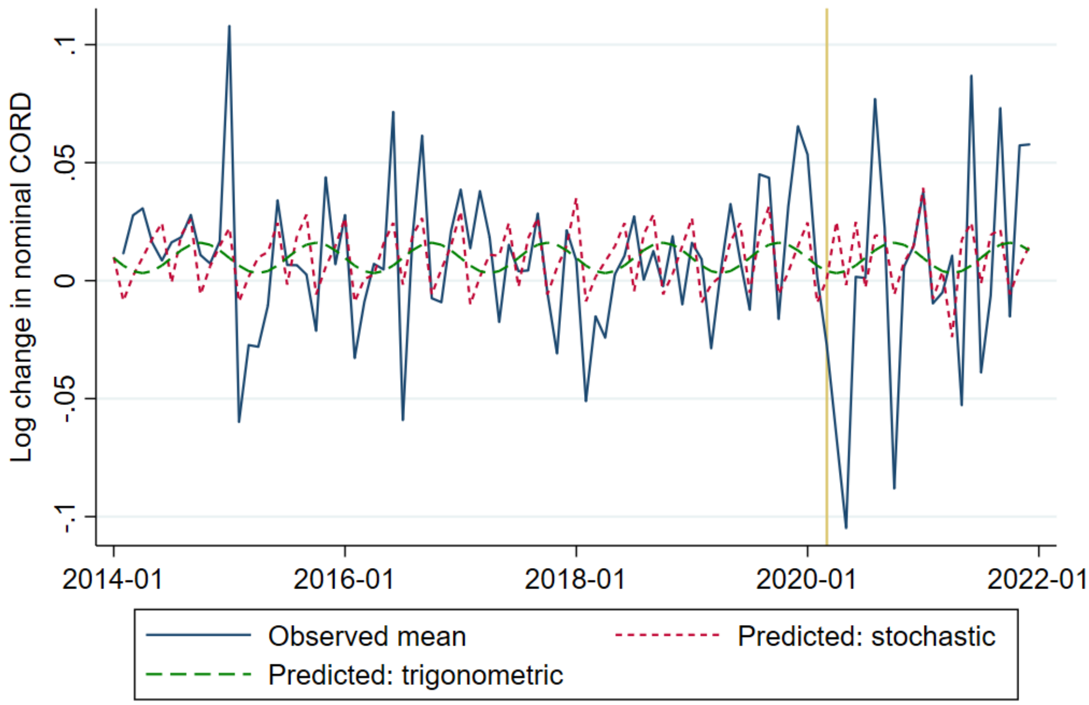
Legend: Maximum variety month (blue shading); Minimum variety month (red shading)

Appendix 3.2. Mean cost of the recommended diet (CoRD) in 45 GN Divisions, by month of follow-up, deflated by non-food CPI (constant December 2020 LKR)

	Dec '20	**Jan '21**	**Feb '21**	**Mar'21**	**Apr '21**	**Jul '21**	**Sep '21**	**Oct '21**	**Nov '21**	**Dec '21**	**Change***
	LKR	*LKR*	*LKR*	*LKR*	*LKR*	*LKR*	*LKR*	*LKR*	*LKR*	*LKR*	%
Fruit	20	28	24	27	30	26	27	31	27	27	35
Vegetables	35	40	40	38	36	42	46	39	45	52	59
Protein-rich foods	18	16	18	19	18	22	22	23	25	23	43
Starchy staples	30	28	31	29	30	30	31	32	34	35	19
Dairy	50	42	45	46	45	42	58	50	51	52	11
Nuts and oils	5	5	5	5	5	4	5	4	5	4	15
CORD	155	155	163	164	165	166	177	173	187	196	25

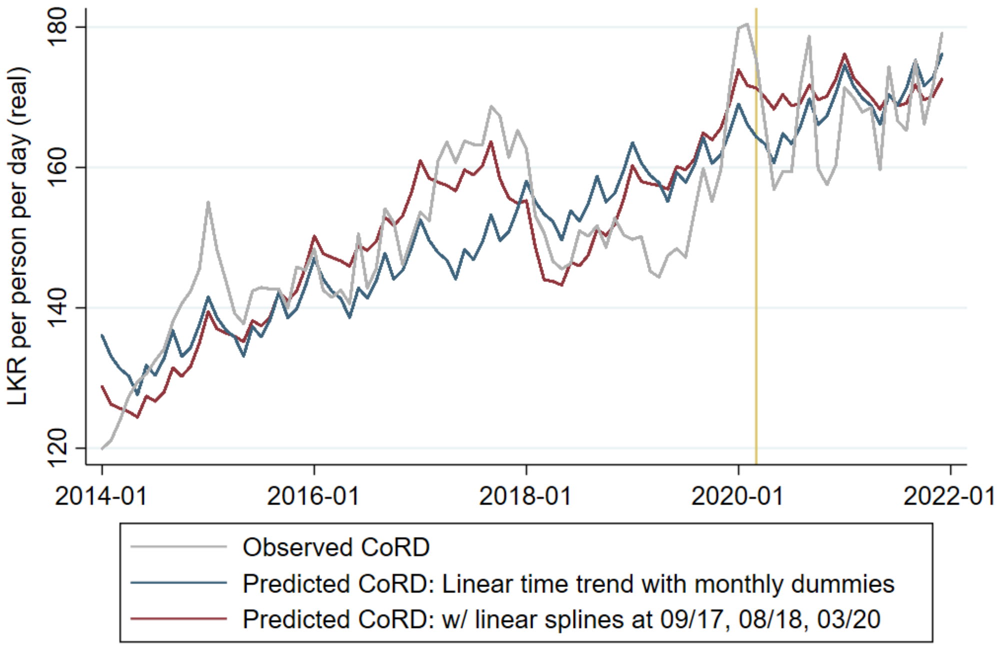
* Change is measured as the average change from December 2020 to December 2021 across the 45 GNs

Appendix 3.3. Log change in the abbreviated cost of a healthy diet (CoRD) using national food price surveillance data, modeled using trigonometric and stochastic trend models, January 2014 – December 2021



Note: Vertical line demarcates March 2020, beginning of Covid-19 in Sri Lanka)

Appendix 3.4. Observed and predicted abbreviated CoRD based on national food price surveillance data, adjusted for non-food CPI, using linear time trends and linear splines with monthly dummies, January 2014 – December 2021



Note: Vertical line demarcates March 2020, the beginning of Covid-19 in Sri Lanka

Appendix 4. Curriculum Vitae

QUINN MARSHALL

1010 N. Calvert Street, Apt. 2
Baltimore, MD 21202

Program in Human Nutrition
Department of International Health
The Johns Hopkins University
Bloomberg School of Public Health
615 North Wolfe St., Room W2041
Baltimore, MD 21205
Email: qmarsha1@jhu.edu

EDUCATION

2017 – Present	PhD, Human Nutrition, The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD.
2011 – 2013	Master of Public Administration in Development Practice, School of International and Public Affairs, Columbia University, New York, NY.
2000 – 2004	Bachelor of Arts, Finance and Information Systems, Smith School of Business, University of Maryland, College Park, MD.

PROFESSIONAL EXPERIENCE

2020 – Present	PhD Candidate, Department of International Health, The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD. Responsibilities: Leading a phone-based food security assessment of 1,020 urban poor, rural smallholders, and estate households in Sri Lanka during COVID-19. The study is a partnership between the World Food Programme (WFP) and Wayamba University of Sri Lanka.
2019 – Present	PhD Candidate, Department of International Health, The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD. Responsibilities: Leading a study to characterize food environments and food affordability in rural communities of Sri Lanka and assess their influence on dietary quality. This is a sub-study within the R5N project, carried out in partnership with the International Food Policy Research Institute (IFPRI), WFP, and the University of Peradeniya.
2018 – Present	Research Assistant, The Johns Hopkins University, Berman Institute of Bioethics, Baltimore, MD. Responsibilities: Supporting the development of a food systems dashboard to inform country-level actions to improve diets and nutrition, through the development of a food systems typology, a food systems diagnostic approach, and the curating of a dataset to characterize food supply, food environments, consumption, health, and environmental outcomes.
2020	Consultant, United Nations Children’s Fund, New York, NY.

Responsibilities: Prepared a background note on achieving healthy diets within environmental limits for children and adolescents for a workshop organized by the United Nations Children's Fund (UNICEF) and EAT in Olso, Norway.

2018 – 2019 Research Assistant, Department of International Health, The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD.
Responsibilities: Conducted a policy landscape evaluation for East and Southern Africa to assess policy support for complementary feeding, as part of a collaboration between UNICEF and Johns Hopkins University.

2017 – 2018 Research Assistant, Institute for International Programs, The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD.
Responsibilities: Assisted with the design of an evaluation to assess Ethiopia's progress towards fulfilling its 'Seqota Declaration', a multisectoral strategy to eliminate stunting.

2015 – 2017 Nutrition Program Officer, Nutrition Division, World Food Program, Rome, Italy.
Responsibilities: Developed corporate guidance for nutrition-sensitive programming for all of WFP's program areas (including social protection and safety nets, general food assistance, school feeding, resilience, and smallholder food procurement), conducted capacity building activities, and managed an external partnership to identify research opportunities for nutrition-sensitive programming.

2013 – 2015 Nutrition Policy Officer, Nutrition Advisory Office, World Food Program, Rome, Italy.
Responsibilities: Provided policy support related to emerging evidence and global developments in nutrition to senior management, Regional Bureaus and Country Offices, and supported WFP's involvement in global partnerships related to nutrition and HIV, including the Scaling Up Nutrition Movement and UNAIDS.

2014 Nutrition Program Officer, South Sudan Country Office, Juba, South Sudan.
Responsibilities: Supported implementation of the WFP-UNICEF Joint Scale Up Strategy for Nutrition as part of the ongoing emergency operation, including high-level strategic discussions with UNICEF and NGO partners and food distributions.

2013 Consultant, Nutrition Section, United Nations Children's Fund, New York, NY.
Responsibilities: Supported knowledge management activities related to the Children, Food Security, and Nutrition Joint Programs of the MDG Achievement Fund, a United Nations inter-agency, multisectoral effort to reduce malnutrition.

2012 – 2013 Consultant, World Bank-Global Forum for Rural Advisory Services, New York, NY.
Responsibilities: Conducted a landscape analysis of rural agriculture extension and advisory services and how they have integrated nutrition.

2012	Field Researcher, Center for Climate Risks and Opportunities Management, Bogor Agriculture University, Central Kalimantan, Indonesia. Responsibilities: Conducted field interviews with government stakeholders and farmers to identify critical knowledge and capacity gaps for improving fire management in the Kapuas district.
2008 – 2011	Permissions Editor and Business Manager, New Directions Publishing, New York, NY.
2007 – 2008	Paralegal, Litigation Section, Akin Gump Strauss Hauer & Feld, LLP, Washington, DC.
2004 – 2006	Small Business Development Volunteer, United States Peace Corps, Piura, Peru. Responsibilities: Designed and managed a pilot project funded by USAID aimed at improving pig farming practices at the household level through construction of corrals, improved hygiene, and business training. Trained local farming organizations in basic accounting and business skills.

PROFESSIONAL ACTIVITIES

Memberships

American Society for Nutrition (ASN)
Agriculture to Nutrition Community of Practice (Ag2Nut)
Global Forum on Food Security and Nutrition (FSN Forum)

Advisory Panels

United Nations Rome-Based Agencies (RBAs) Working Group on Sustainable Value Chains for Nutrition, 2016-2017.
Committee on World Food Security (CFS) Technical Task Team on Nutrition, 2015-2017.

LANGUAGES

Spanish – fluency, both written and oral
Italian – moderate fluency, both written and oral

HONORS AND AWARDS

2018 – 2022	Center for a Livable Future-Lerner Fellowship, The Johns Hopkins University, Baltimore, MD
2019	Elsa Orent Keiles Fellowship, The Johns Hopkins University, Baltimore, MD
2019	Kruse Student Publication Award, The Johns Hopkins University, Baltimore, MD

2018	Summer Research Fellowship, Food and Agriculture Organization, Rome, Italy
2018	Humanitarian Assistance Scholarship, The Johns Hopkins University, Baltimore, MD
2017	Baker, Reinke, Taylor Scholarship in International Health, The Johns Hopkins University, Baltimore, MD
2012	Departmental Fellowship, School of International and Public Affairs, Columbia University, New York, NY.
2004	Dean's Meritorious Service Award, Smith School of Business, University of Maryland, College Park, MD.
2003	Accenture Leadership Scholarship, Smith School of Business, University of Maryland, College Park, MD.

PUBLICATIONS

Author, Co-author

- 2022, A. Herforth, A. Bellows, **Q. Marshall**, R. McLaren, T. Beal, S. Nordhagen, R. Remans, N. Estrada Carmona, J. Fanzo. Diagnosing the performance of food systems to increase accountability
  towards healthy diets and environmental sustainability. Forthcoming.
- 2021, **Q. Marshall**, J. Fanzo, C. Barrett, A. Jones, A. Herforth, R. McLaren. "Building a global food systems typology: A new tool for reducing complexity in food systems analysis." Frontiers of Sustainable Food Systems, 5: doi: 10.3389/fsufs.2021.746512
- 2021, **Q. Marshall**, A. Bellows, R. McLaren, A. Jones, J. Fanzo. "You say you want a data revolution? Taking on food systems accountability." Agriculture, 11(5): 422-38.
- 2020, C. Barrett, T. Benton, J. Fanzo, **et al**. "Socio-technical Innovation Bundles for Agri-food Systems Transformation: Report of the International Expert Panel on Innovations to Build Sustainable, Equitable, Inclusive Food Value Chains." Cornell Atkinson Center for Sustainability and Springer Nature. Ithaca, NY and London.
- 2020, D. Olney, **Q. Marshall**, G. Honton, K. Ogden, M. Hambayi, S. Piccini, A. Go, A. Gelli, L. Bliznashka. "Leveraging an implementation-research partnership to improve effectiveness of nutrition-sensitive programs at the World Food Programme." Food and Nutrition Bulletin, 41(1):18-37
- 2017, WFP Nutrition Division. "Unlocking WFP's potential: Guidance for nutrition-sensitive programming", version 1.0. World Food Program.
- 2017, D. Hunter, B. Giyose, A. PoloGalante, F. Tartanac, D. Bundy, A. Mitchell, T. Moleah, J. Friedrich, H. Alderman, L. Drake, R. Kupka, **Q. Marshall**, K. Engesveen, and S. Oenema. "Schools as a system to improve nutrition: A new statement for school-based food and

nutrition interventions." Discussion Paper. United Nations Standing Committee on Nutrition.

- 2017, J. Fanzo, S. Downs, **Q. Marshall**, S. de Pee, M. Bloem. "Value chain focus on food and nutrition security." In *Nutrition and Health in a Developing World*, 3rd edition. S. de Pee, D. Taren, and M. Bloem eds. Humana Press. New York, NY.

- 2015, J. Fanzo, M. Graziose, K. Kraemer, S. Gillespie, J. Johnston, S. de Pee, E. Moterrosa, J. Badham, M.W. Bloem, A. Dangour, R. Deckelbaum, A. Dobermann, P. Fracassi, S.M. Moazzem Hossain, J. Ingram, J. Jerling, C.J. Jones, S. Indrayana Jap, L. Kiess, **Q. Marshall**, K. Martin, A. Narayan, M. Amuyunzu-Nayamongo, F. Pepping, K. West, "Educating and training a workforce for nutrition in a Post-2015 world." Advances in Nutrition, 6: 639-47.

- 2015, J. Fanzo, **Q. Marshall**, D. Dobermann, J. Wong, R. Merchan, M. Jaber, A. Souza, N. Verjee, K. Davis, "Integration of nutrition into extension and advisory services: A synthesis of experiences, lessons, and recommendations." Food and Nutrition Bulletin, 36(2): 120-137.

- 2014, F. Terki, S. de Pee, J.M. Claros, **Q. Marshall**, L. DuRant, "Nutrition assessment, counseling and support for adolescents and adults living with HIV: a programming guide." UNAIDS.

- 2012, J. Wong, **Q. Marshall**, A. Jay, and R. Boer, "The Use of a Seasonal Fire Early Warning Tool for Managing Peat Fires in Indonesia," Climate Services Partnership.

Advisor, Contributor

- 2017, WFP. "The potential of Food Assistance for Assets (FFA) to empower women and improve women's nutrition: a five-country study." World Food Program.

TEACHING

2018 – 2019	Teaching Assistant, Food and Nutrition Policy Course. The Johns Hopkins University, Bloomberg School of Public Health, Baltimore, MD.
2018	Guest Lecturer, Global Issues in Public Health Nutrition. New York University, College of Global Public Health. Lecture on food systems, food environments, and value chains for nutrition.
2013	Departmental Research Assistant, Macroeconomics, School of International and Public Affairs, Columbia University, New York, NY.
2012	Departmental Research Assistant, Foundations of Sustainable Development, School of International and Public Affairs, Columbia University, New York, NY.

PRESENTATIONS AND POSTERS

2021 Agriculture, Nutrition, and Health (ANH) Academy Research Conference 2021. Virtual. “Characterizing the food environment in rural communities of Sri Lanka: Baseline findings from 45 Grama Niladhari Divisions.”

2021 Agriculture, Nutrition, and Health (ANH) Academy Research Conference 2021. Virtual. “Assessing food security status among urban and rural vulnerable groups of Sri Lanka during COVID-19: findings from a longitudinal study” (poster)

2014 Institute for Development Studies, Brighton, UK. “Food systems and value chains for people living with HIV.”

2014 UNAIDS Inter-Agency Task Team on Food, Nutrition and HIV. Cape Town, South Africa. “Kheth’Impilo: Linking health and support services for communities.”

ADDITIONAL INFORMATION

Personal Statement

I have thirteen years of experience working as a practitioner and researcher in the fields of international development and nutrition. As a practitioner, I have worked at country-level in low and middle-income countries—including in remote settings—as well as at global-level, on program design, implementation, monitoring and evaluation, especially related to agriculture and safety net programs that address nutrition. As a researcher, I am focused on improved methods and metrics for monitoring food systems, in particular food environments and markets, and how these may inform program design and evaluation.

Key Words

Nutrition
Food Systems
Food Environments
Food Affordability
Program Evaluation